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MILL ARCHITECTURE.*

BY C. JOHN HEXAMER.

The first principle in architecture, and foremost in buildings intended for manufacturing purposes, is utility; and all other considerations are subservient to it. The elements of Vitruvius—*firmitas, utilitas, venustas*, stability, utility, beauty—still hold good. That mill building is the best which is best suited for its purpose, and that architect is most expert, who exactly knows what changes in his plans are required for every department of manufacture. I, of course, do not mean to say that a mill should be erected in bad proportions "a hideous mass of stone, an eyesore to mankind;" on the contrary, an architect shows his superior skill if, notwithstanding the small amounts usually allotted to decorative purposes, and the fetters which that tyrant utility places on him, he is still able to erect an evenly proportioned, well-looking building. The higher a building is, the better should be its construction. The simplest of all rules of building, to construct a building safely and solidly, is frequently neglected. The great principle in fire constructions is to divide the building into numerous parts, and then to construct these parts in such a manner and of such a material that a fire originating in any one part may be restricted to it. The main great divisions into which a manufacturing place is divided are the stories.

* A lecture delivered before the Franklin Institute, December 17, 1884.

It becomes our problem then to construct each story so that a fire starting in one, may be restricted to that story; so that smoke, fire and water used to extinguish the flames, may not harm other stories and their contents. To arrive at this result there must be no openings in the floors; that is, the elevators and stairways must be outside of the main building, and belt and other openings must not break the floors. In order to accomplish this we must place stairways and elevators in separate stairway and elevator houses, the walls of which should be of sound brick and of sufficient thickness. The walls should only be broken by the doors leading into the separate stories. These doors should be iron-lined on both sides, and should be self-closing (either by a spring or weight) the doors being held open by a piece of fusible solder, which melts at any considerable rise of temperature.

The practice of putting in wooden sills, and lining them on top with sheet iron, is to be deprecated, as the woodwork of the adjoining floors forms a juncture with the wooden sill, and a fire will be transmitted underneath the iron. The elevator openings in the elevator house should be self-closing, so that a double security—the elevator doors and the doors leading into the main building—may be had. Especial care should be taken to extend the walls of the stairway and elevator house through the roof of the main building, thus cutting the trussing and timbering of the roofs, so that a fire may not be transmitted through the woodwork of the roof. A good-sized ventilator should be placed over the elevator house, so that in case of fire the smoke may escape through this—like a chimney—thus making it easier for firemen to see and work, and for employés to escape from the building; this is of so much importance that the Philadelphia Fire Underwriters' Tariff Association has made it a requirement in hotel buildings. Great care must be taken to keep the bottom of elevator houses free from waste and rubbish as these by igniting either spontaneously, or by a burning object being thrown into them, have caused many fires. The safest construction for a stairway house is that used at the Ontario Mills, of the Arrott Steam Power Mill Company, in which the stairway house is entirely cut off from the main mill by blank coped walls without any direct communication with the mill, the communication between the mill and the stairway house being effected by means of iron porches on the outside of every story.

FLOORS.

The safest floor, which has for a long time been used in fire-proof construction, is one consisting of brick arches, sprung between iron girders. In order to be of practical value, the spans must not be too large, as iron, which is an excellent conductor, soon warps by unequal expansion in case of fire, and is apt to throw out the intervening arches. When spans are large, the intervening arches readily drop out of the girders which hold them, and thus entire buildings, which were considered fire-proof have been totally destroyed. Care must, therefore, be taken to cover all exposed iron surfaces with a poor conductor of heat.

A construction much used in France, which has proved successful in many cases, is an iron girder with concrete arches, the arches being formed by means of moulds and held together with tie rods until dry. When good concrete dries, it becomes as hard as stone, and being an excellent non-conductor of heat, when properly erected, so as to surround the entire iron work, keeps the iron from becoming heated and and warping.

Iron girders have also been used in conjunction with terra cotta, and with the so-called terra cotta lumber. Terra cotta lumber is a material manufactured from clay and saw-dust. The clay mixed with saw-dust, is formed into the required shape, then dried, and burned in a kiln; the organic part is destroyed, and a porous mass remains which may be worked with a chisel like lumber. Tests which have been made with this material in New York have proved very satisfactory.

[A number of slides were then shown, illustrating the manner in which these different materials are used and erected.]

A concrete floor, when made with good cement, is, next to a brick arched floor, the best known. This substance forms into one solid, hard, rock-like mass, and those who have seen the works in France, where entire churches and aqueducts have been built with it, can no longer doubt its efficiency. It may be well remembered how at the great fire of the Jayne building, in Philadelphia, an ordinary mortar floor saved the second story. The problem then is, "How can we construct a cheap, light and effectual floor?"

A solid three-inch plank floor, laid flat, tongued and grooved, with one and a quarter inch flooring boards on top arranged for flooding, is

the usual manner in which the floors of mills are now laid. These can be much improved if, between the plank and flooring boards, a layer of good mortar or concrete is inserted, making an excellent, slow burning floor. Asbestos paper, or better the thicker asbestos mill board, is sometimes used with good effect, between the flooring boards and plank; although it has been claimed by some that the asbestos is hygroscopic and attracts the moisture from the flooring, causing the boards to rot. I have never experimented to any extent with this material, and cannot therefore, express an opinion on its merits or demerits.

All floors should be arranged for flooding. This is accomplished by raising all sills and other openings through which water may escape. A floor arranged for flooding, when otherwise well laid, is one of the best means for restricting a fire from extending from one room to another, for, as soon as the fire appliances, such as sprinklers, hose, etc., are turned on, there is, in a very short time, a pond of an inch or an inch and a half deep formed on the floor, which prevents the floor from igniting; at the same time, a rise in temperature vaporizes the water on the floor, causing the formation of steam, which aids in extinguishing the fire.

We are now fairly well protected from fire, smoke and water from above, how then are we to protect the wooden ceiling in case of a fire from below? The simplest (but costly) method would be to iron-line all wood-work; another would be to cover the wood-work by a so-called fire-proof solution. I have experimented with all solutions which I could learn of; but as I have not time to go into details on this part of the subject I must refer you to a series of articles in the *Spectator* in which I have described the results of my experiments.

It is well known, that several preparations exist which render wood impervious to heat, and, at the same time, increase its durability. Some of the solutions have been tried on a large scale, and have proved themselves successful wherever used. Although these measures are cheap, and their success demonstrated, they have, with few exceptions, (as for example, at Frankfort-on-the-Main, the Hof Theater at Berlin, and several German manufactories), not been employed. Perhaps the general public will, in view of frequently recurring catastrophies, at last comprehend that even the retardation of the combustion of wood-work would be of inestimable value in securing immunity from fire, and that the spreading of flames will be greatly retarded if, instead of burning rapidly, as dry wood will, it slowly chars into coal.

The nature of wood makes it an easy matter to change it into a state frequently, though incorrectly, called fire-proofed. On account of its porosity, a solution applied to its surface sinks deeply into its pores, thereby attaining a firm hold, and on account of its rigidity exposes only the covering to abrasion. Care should be taken where such solutions have been used, to replenish them, from time to time, so as to keep the wood entirely covered.

Asbestos paint is a clean and excellent coating for wood, and still better, the thicker asbestos concrete. These substances act like true paints, adhere tightly to the wood, give protection against high temperatures, and do not readily rub or chip off. It has but one objection; that is, its solubility in water; it cannot be used in places exposed to the action of water, but for most interior purposes this is no material objection. Great care must be taken in purchasing this article and it should always be tested before being used, as much of the so-called "asbestos paint" which is sold is entirely worthless.

Ordinary whitewash is a cheap and excellent coating against fire. It adheres tightly to the wood, impregnating it to a certain depth, and, when frequently replenished will form an excellent protective coating.

Wood, impregnated with ammonium sulphate, transforms it into a condition which has frequently, but incorrectly been termed "fire-proof." Ammonium sulphate keeps the wood from burning with a flame, and only those parts which come in direct contact with fire are charred, but the parts in contact with flame, even in charring, will not transmit the fire any further. Numerous experiments which I have made with ammonium sulphate, have, in every instance, proved successful. At the severe fire of a large chemical works where parts of the wood impregnated with this substance, in direct contact with the flames, were charred, the adjacent parts remained intact.

When ceilings are plastered, this should be done with wire netting and the plaster laid on it, especial care being taken that the netting follows the outlines of the ceiling closely, so that no hollow spaces occur. The correct method is to avoid all hollow spaces, in which dirt may accumulate and fire travel. The so-called "sealed" ceilings, that were formerly in vogue, should always be avoided.

GIRDERS.

Girders should be solid. When it is necessary to use compound girders, they should be tightly bolted together, so as to leave no inter-

vening spaces. In storehouses, etc., where there is but little vibration, girders may be inserted in the wall by placing them either on brackets or a short distance into the wall, with bevelled edges, without any further anchoring. In mills, where the amount of vibration is great, Woodbury advises to securely bind the beam to the wall by embedding in the masonry a flat cast-iron plate with a transverse fin upon each side near the end, one to secure the plate in the wall and the other in a groove across the under side of the beam, firmly secured by wedges driven in at each side of the fin. The bricks in the wall for about five courses above the beam should be laid dry, and the upper edge of the beam at the end slightly rounded, and an air space should be provided at each side of the beams.

Under no consideration should the old-fashioned anchorage of fastening the girder on the outside of the wall with a large anchor plate be used, as when the beams burn through, the leverage brought to bear on the wall will overturn it.

[Numerous slides were here shown, illustrating the different modes of anchorage and the construction of girders.]

WALLS.

Brick is the best material for fire construction. It stands long after granite has disintegrated and marble has been burnt into lime. Iron fronts are to be deprecated, and especially such shells of iron as are frequently erected, without even a brick filling. Sandstones, when the sand particles are held together by a good binding material are serviceable, but those in which the sand particles are held together by lime should not be used in building. Granite is a very poor stone for fire construction, as its inter-molecular spaces contain water, which, on being heated vaporizes into steam, causing the disintegration of the stone. Marble is also a poor material to use, as, on becoming heated, it is decomposed, carbonic acid and burnt lime being formed. For this reason, lintels over doors, windows, etc., should never be made of marble, granite, or poor sandstones. Preferably, a brick arch should be sprung. Good brick buildings have frequently been destroyed by having poor stone lintels over driveways and so on, which were destroyed by fire, causing the falling of the brick wall. Where further ornamentation is required, terra-cotta ornaments may be used; these are now manufactured in all shapes and varieties.

CORNICES.

Where cornices are used, these should be of brick or terra-cotta. Under no circumstances should "wood-boxed" cornices be used, as these transmit the fire from one part of the building to the other, and for this reason, even hollow metal cornices are objectionable, as they form flues along which the flames travel.

COLUMNS.

The best column to stand in case of fire is a good hard wood column, without taper, bored near the top and bottom so as to prevent dry rot, lined with sheet iron or any other metal, or covered with a good protecting substance. Of all columns, those of exposed cast iron are the poorest. These, on even a slight rise of temperature, readily disintegrate, especially when water is poured upon them. Wrought iron, on being exposed to high temperatures, expands and warps. Exposed iron, therefore, is the most untrustworthy of all materials for column construction.

In order to protect iron columns from surrounding temperatures numerous plans have been devised to cover them with non-conductors. The columns constructed by Mr. Wight, of Chicago, are excellent for this purpose. Terra-cotta lumber has been used for this purpose, as well as plaster and mortar. Ordinary lime mortar or concrete is preferable to a gypsum composition, as this readily corrodes the iron. Care must be taken to surround all parts of columns exposed to abrasion, the base should have a hood of wood.

[Numerous illustrations of improved columns were then shown.]

ROOFS.

There is no part of a building which is put to such a severe wear and strain as the roof; being, at certain times of the year, exposed to high temperatures on the inside, and to very low temperatures on the outside. A good roof should be of three inch plank, tightly fastened together, protected on the inside with sheet iron or other metal, asbestos concrete, or with a wire netting tightly fastened on, so as to leave no hollow spaces, and the plastering placed on this; a good metal covering being placed on the outside with nails counter-sunk and stopped with putty. Slate makes a poor covering, as by a rise in temperature it readily disintegrates.

FIRE DOORS.

There are few parts in fire construction which are of so much importance, and generally so little understood, as fire doors. Instances of the faulty construction of these, even by good builders and architects, may daily be seen. Iron doors over wooden sills, with the flooring boards extending through from one building to the other, are common occurrences. We frequently find otherwise good doors hung on to wooden jambs by ordinary screws. Sliding doors are frequently hung on to wood work, and all attachments are frequently so arranged that they would be in a very short time destroyed by fire, and cause the door to fall. In case of fire, a solid iron door offers no resistance to warping. In an iron-lined door, on the contrary, the tendency of the sheet iron, to warp, is resisted by the interior wood, and when this burns into charcoal, it still resists all warping tendencies. I have seen even heavily braced solid iron doors warped and turned after a fire, having proved themselves utterly worthless. It is needless to say that when wooden doors are lined, they should be lined on both sides; but frequently we find so-called fire-proof doors lined on one side only.

Good doors are frequently blocked up with stock and other material, so that in case of fire they could not be closed without great exertion, or they have been allowed to get out of order, so that in case of fire they are useless. This has been so common that it has given rise to the jocular expression of insurance men, when they are told that a fire door exists between two buildings, "Warranted to be open in case of fire." The strictest regulations should exist in regard to closing the fire doors nightly. Frequently we find that although the fire door, and its different parts, are correctly made, there are other openings in the wall which would allow the fire to travel from one building to the other, such as unprotected belt- and shaft-holes. That a fire door may be effective, it must be hung to the only opening in the wall.

The greatest care must be exercised to keep joists from extending too far into the wall, so as not to touch the joists of the adjacent building, which would transmit the flames from one building to the other in case of fire. A good stone sill should be placed under the door, and the floor thereby entirely cut. Sills should be raised about one and a half inches above the level of the floor, in order to accomplish the necessary flooding of the same. If stock must be wheeled from one building to the other, the sill can readily be beveled on both sides of

the wall, allowing the wheels to pass readily over it. Lintels should consist of good brick arches. When swinging doors are used, they should be hung on good iron staples, well walled into the masonry, and the staples so arranged that the door will have a tendency to close by its own weight. The door should consist of two layers of good one and a quarter inch boards, nailed crosswise, well nailed together and braced, and then covered with sheet iron nailed on, or if of sheet tin, flanged, soldered and nailed. Particular care should be taken to insert plenty of nails, not only along the edge of the door, but crosswise in all directions. I have seen cases, in which nails had only been placed along the edges, where the entire covering had been ripped off through the warping tendencies of the sheet iron.

The hinges on these doors should be good strap hinges, tightly fastened to the door by bolts extending through it, and secured by nuts on the other side. Good latches, which keep the door in position when closed, should always be provided. In no case should the door be provided with a spring lock, which cannot be freely opened, as employés might thereby be confined in a burning room.

Sliding doors should be hung on good wrought iron run-ways, fastened tightly into the wall. Wooden run-ways, iron lined, which we frequently see, are not good, as the charring of the wood in the interior causes them to weaken and the doors to drop. Run-ways should be on an incline, so that the door when not held open will close of itself. Care must be taken to have a stop provided in the run-way, so that the doors may not, as I have frequently seen them, overun the opening which it is to protect. Doors should overlap the edges of the openings on all sides. Large projecting jambs should never be used.

All doors contained in "fire-walls" should have springs or weights attached to them, so as to be at all times closed. Fire doors can be shut automatically by a weight, which is released by the melting of a piece of very fusible solder employed for this purpose. So sensitive is this solder that a fire door has been made to shut by holding a lamp some distance beneath the soldered link and holding an open handkerchief between the lamp and link. Though the handkerchief was not charred, hot air enough had reached the metal to fuse the solder and allow the apparatus to start into operation.

These solders are alloys more fusible than the most fusible of their component metals. A few of them are—Wood's alloy, consisting of:

Cadmium	1 to 2 parts.
Tin	2 "
Lead	4 "
Bismuth	7 to 8 "

This alloy is fusible between 150° and 159° Fahr. The fusible metal of d'Arcet is composed of:

Bismuth	8 parts.
Lead	5 "
Tin	3 "

It melts at 173·3°. We can, therefore, by proper mixture, form a solder which will melt at any desirable temperature.

Numerous devices for closing doors automatically have been conconstructed, all depending upon the use of the fusible solder catch. catch.

[Various automatic doors were then explained with the aid of stereopticon views.]

CONSTRUCTION OF PICKER-HOUSES.

The proper construction of that hazardous part of a mill, the picker-house, is of the utmost importance. Frequently we find picker-houses, otherwise well constructed, with some fault which endangers the whole structure. Glass transoms above iron doors, between the main mill and the picker-house, may sometimes be seen, while large belt holes in the protecting wall are very common. These will readily convey fire from the picker-room to the mill. It is difficult to protect belt openings by iron slides. It is therefore better to have power conveyed from the mill to the picker-room by means of shafting. When journal-boxes are set in the wall, small apertures only are required.

A frequent mistake in picker-houses is to leave the windows in the wall of the main mill above the picker-house, unprotected by iron or iron-lined shutters. Picker-houses are generally one story high, and the flames striking upwards are thereby communicated to the mill. The ventilators and skylights in the roof of the picker-house increase the danger from these sources. Windows in the picker-house, facing the mill, may also frequently be found. These, if possible, should be dispensed with. If they are absolutely necessary, good iron-lined shutters should be provided, which should in all cases be arranged to close from the outside. Frequently, enclosed gangways connect the picker-

house with the main mill. These should be constructed of corrugated iron, with good iron-lined doors at both ends. If these are not arranged to close automatically in case of fire, they should be so fixed that they may be closed from the outside without entering the gangway. A great mistake, frequently made, is to store stock in the gangway, or to allow waste and other rubbish to accumulate in the same. In case of fire, this may act as a conductor for the flames to extend from one building into the other, before the opportunity is seized to close the fire doors.

Brick, stone or cement, floors should be used in the picker-house. Wooden window-jambs and casings should not be used; while substantial iron, or, better still, iron-lined shutters (for solid iron shutters have the demerits of iron doors) should be hung over all openings, extending beyond the edges of the windows. A shutter should be constructed like an iron door, hung on good iron staples built into the wall, and always on the outside of the building. Shutters hung on wooden window casings will, of course, fall as soon as the wood-work is destroyed. Iron shutters should never be placed on the inside, as it is absurd to expect that anyone will remain inside of a burning building to close shutters.

CARD-ROOMS.

The card-room should be as large and as well ventilated as possible. The ceilings should be high, and should contain as few projections as possible, as these will cause the "fly" to settle on them. The card-room should be wide enough to allow the placing of the cards in sets side by side, with sufficient space between the sets to allow the cleaner to pass freely around them.

TRANSMISSION OF POWER.

All driving fixtures should be contained in separate houses, constructed like a stairway or elevator-house, cut off from the mill by coped fire walls, as a fire will be carried from story to story through belt openings and boxes. Particular attention should be given to belt boxes, where they are used, to keep them at all times scrupulously clean from waste fly and so on. Belt boxes should be provided with a good supply of automatic sprinklers. Objections have been raised to sprinklers by some, for the reason that should they be opened by accident, the belts would be damaged by water. Mr. Edward Atkinson has suggested that the belts be enclosed in a glass chamber, and

that automatic sprinklers should be placed outside of the glass. This arrangement, I understand, has worked well in practice.

All dangerous journals throughout a mill should be provided with automatic alarms, which give a signal as soon as a journal becomes dangerously hot. One of the best, the Journal Thermostat of Whitaker, consists of a U-shaped glass tube, with arms of equal length, one of which is closed. The left arm contains a small amount of a volatile liquid hydro-carbon, and the remainder is filled with mercury. When the temperature of the journal rises beyond a certain point, the hydro-carbon is vaporized, and forces out the mercury, which, in collecting in the receptacle below, closes an electric circuit, which gives the alarm.

[Various slides were shown for further illustration.]

HEATING.

The old primitive method of heating by stoves is rarely found in the better class of mills. Where these are used, care should be taken that they are placed on metal, with good stove pipes, passing into chimneys, the stove-pipes being tightly wedged into the wall, so as to keep them from disengaging and allowing sparks to fall into the room. Under no consideration should stove-pipes pass out of windows.

The safest system of heating is by hot water. In this case, the heat is produced by radiation from pipes filled with hot water, the same being heated in a boiler, preferably outside of the mill.

Steam is usually employed for heating in mills. Special care should be taken to have the pipes free from wood-work, and away from all places where dust, dirt, waste, etc., may accumulate. Steam pipes should be hung along the ceiling, about 24 inches below it, in preference to the old fashion, along the sides of the room, where stock and waste are frequently piled. The theory, so frequently advanced, that, if pipes be hung below the ceiling, the same amount of heat cannot be obtained as when they are hung along the sides, is erroneous. The following table, which shows the results of a series of experiments made by Mr. C. J. H. Woodbury, demonstrates this fact.

Hourly thermometrical observations were taken in a room, 75 x 400 feet, supplied with five rows of steam pipes, against the walls near the floor, in the first instance; and in the second there were four rows of pipe around the room, two feet from the walls and hung the same dis-

tance below the ceiling, requiring only three-quarters as much pipe as in the first instance.

Mean Temperature by Hourly Readings.

Thermometers hung in centre of room.	Degrees Fahrenheit.	
	Pipes at side. Dec. 29 to Jan. 5.	Pipes elevated. Jan. 29 to Feb. 5.
Sixteen inches from ceiling	80·05°	80·80°
Midway	76·52°	76·90°
Sixteen inches from floor	77·08°	77·00°
Average	77·88°	78·23°

The reasons why steam pipes ignite wood are twofold. First, in the case of superheated steam, we have a regular combustion going on; in the second case, with steam pipes containing steam, at the usual temperature, we have a secondary phenomenon of spontaneous combustion. In the latter case, the steam pipes slowly dry the wood, the contained moisture being vaporized, and at last the wood assumes a state resembling that of charcoal; when in this condition, combustion may take place spontaneously.

At a discussion before the French Academy, in 1879, this was brought out clearly. M. Cosson described an accident which had occurred in his laboratory a few days before. While the narrator was working in the laboratory, a portion of the boarding of the floor spontaneously took fire. The boards were in the vicinity of an air-hole, fed with warm air from a stove four metres away on the floor below. A similar accident had occurred two years ago, and in consequence M. Cosson had the boards adjoining the air-hole replaced by a slab of marble. The boards which now ignited adjoined the marble. The heat to which the boards were subjected was, however, very moderate, being only that of air at 25°C. (77°F.) Nevertheless, M. Cosson said the wood had undoubtedly been slowly carbonized. Being thus rendered extremely porous, a rapid absorption of the oxygen of the atmosphere had resulted and sufficient heat was thereupon produced to originate combustion. The danger thus disclosed, said M. Cosson, is one to which the attention of builders ought to be directed. In the instance in question, M. Cosson was able to extinguish the fire with a little

water, as he was present and witnessed its beginning; but had it occurred at night, during his absence, it would undoubtedly have completed its work of destruction. M. Fayé stated that at Passy, a few days before, a similar case of spontaneous fire, due to the action of the warmth from the air-hole of a stove upon the wood-work, had occurred at the house of one of his friends.

Mr. C. C. Hine, editor of the *Monitor*, relates the following: "The Institute of Technology, at Boston, long ago decided upon the danger of steam pipes passing through, and in contact with, wood. It was shown that the wood, by being constantly heated, assumes the condition, to a greater or less degree, of fine charcoal, a condition highly favorable to spontaneous combustion. This is so important and interesting a point that we may be pardoned for enlarging upon it somewhat, in contrast to the brevity of the foregoing paragraphs.

"Steam was generated in an ordinary boiler and was conveyed therefrom in pipes which passed through a furnace and thence into retorts for the purpose of distilling petroleum. Here the pipes formed extensive coils and then passed out, terminating at a valve outside the building. To prevent the steam, when blown off, from disintegrating the mortar in an opposite wall, some boards were set up to receive the force of the discharge, and as often as the superheated steam was blown against them, the boards were set on fire! This occurred in an oil refinery in Pittsburgh, Pennyslvania.

"Some years since, while on a visit to an Institution for the Deaf and Dumb, in Illinois, of which an esteemed friend is principal, we called attention to the manner in which some steam coils were secured to wooden supports, and pronounced them unsafe. They were shown to be a thousand feet or so—as the pipes ran—from the boiler, and our caution only provoked a smile. The next year we visited as usual, and, upon taking the principal's hand, he said—before exchanging salutations or inquiries—'Come with me, I wish to show you something,' and led the way to the room where, a year ago, his attention had been called to the steam pipe. 'There,' said he, 'examine that; I have been saving it for you since last winter; the coil fell down, and investigation showed that the screws had let go because the wood had been turned to charcoal and had no more strength to hold them.' The experience was new to him, it may be old to some of our readers, but its introduction here will illustrate a fact which is now becoming an admitted one among those who have given this matter attention.

"An experiment illustrating the effects of superheated steam was tried as follows: Steam was taken from an ordinary boiler through a pipe forty feet long. Ten feet from the farther end a collar of wood was fitted closely to the pipe; ten feet near the boiler a lighted kerosene lamp was placed under the pipe. In ten minutes the wooden collar was on fire."

LIGHTING.

Numerous fires have been caused by lamps in mills. These should be constructed of metal, and not of glass, as the latter readily breaks High-test oils only, with a flash point of 150 degrees or over should be used.

The watchman should burn lard oil in his lamp, which is safer than mineral oil. In order that he may not, by trimming his lamp in the mill, cause fires, as has been the case, it should be inclosed and provided with a lock and key, the key being fastened in some fire-proof room in the building, so that when the lamp burns poorly, the watchman will have to return to the fire-proof room and trim and fix his lamp there, and not in the mill among the loose stock and material.

In order to increase the safety of lamps, so-called safety lamps have been invented. These are glass lamps inclosed in metal cases, which protect the glass receptacle from breaking. Westland's lamp has, experimentally, proved successful, although I have no further evidence of how it has worked in practice. This consists of a globe of glass, containing the oil, surrounded by a concentric sphere, containing water charged with carbonic acid gas under pressure. As soon, therefore, as the lamp is broken, carbonic acid gas is set free and the flames extinguished.

Gas is the general material yet used for illumination. Gas lights should be inclosed so as to keep stock from falling into the flames, and from igniting fine particles of dust and "fly" in card- and picker-rooms. Especial care should be taken to clean the tops of enclosed gas lights well before lighting up, as many fires have been caused from dirty inclosed lanterns. In order to safely light up gas lights, several devices have been constructed, among which are Mr. Whiting's electric torch, in which the gas is lighted by means of an electric spark. Another is a German device of Bodmer, by means of which an enclosed torch is pressed down over the gas jet and the gas in escaping is lighted.

[Several of these devices were then shown with the aid of projections on the screen.]

Gasoline vapor, or as it is frequently called, gasoline gas, is sometimes used. Where gasoline machines are used, the machines, especially the carburetting arrangement, should be placed at least fifty feet from all other buildings. The gas machine building should be on a piece of ground lower than the other buildings, so that the gasoline vapor which may escape, and which is heavier than air, may flow away from the buildings. Care must be taken to have all supply pipes descend towards the machine building, so that any vapor which may have condensed in its passage from the carburetter of the mill may flow back into the carburetter. Care should be taken to have a drip-cock attached to every jet, so that the pipes may be well emptied of gasoline before lighting the vapor. Gasoline vapor is extremely explosive and dangerous.

Of late an excellent gaslight has been introduced, the so-called Siemens Regenerative Burner. Care should be taken where these are erected, to have the ventilating flues, which carry off the products of combustion, well constructed of metal, free from wood-work, as these lamps give off a great amount of heat, and readily ignite wood-work which is in contact with the ventilating flue.

The electric light is daily coming more into use, and when properly installed is very safe. Daily tests should be made for grounds. Great care should be taken to have all wires properly insulated, all connections in wires well made, the proper amount of cut-outs, switches and safety catches, provided, and where arc lights are used, proper care taken of the glowing carbon points, which, in falling, have caused fires. One of the greatest hazards is caused by improper insulation, as moisture will cause an electric current to pass from one wire to another, especially through water which contains salts, such as lime, which it dissolves in passing through ceilings or walls.

[Numerous illustrations of electric lights were shown, showing their hazards and how they may be safely installed.]

FRICTIONAL ELECTRICITY.

Electricity is frequently caused by the friction of belts on pulleys, a fact known in Germany for a long time, but first described in our country, I believe, by Mr. F. W. Whiting. This has been the cause of fires and

should be guarded against by connecting all parts on which the electricity accumulates, with the ground, by means of wires attached to the object and to a gas-, or preferably, a water-pipe. This is one of the most prolific sources of fires in the heavy coating rooms of oil-cloth factories, as the electric sparks readily ignite the benzine vapors present. In one of the largest Philadelphia works of this kind, the iron receiving racks were so charged with electricity that long sparks could be drawn from them, but since they have been properly "wired," not a trace of electricity is left in them.

THE FUTURE WATER SUPPLY OF PHILADELPHIA.*

BY COL. WILLIAM LUDLOW,
Chief Engineer of the Philadelphia Water Department.

Vice-President FREDERICK GRAFF, introduced COL. LUDLOW, who spoke as follows:

MR. PRESIDENT, LADIES AND GENTLEMEN:—I must admit that I am somewhat taken by surprise when I received the invitation from the very excellent Secretary of the Institute, requesting me to attend the meeting to-night and make some remarks regarding the future supply of the city; I was under the impression that the meeting would resolve itself into an informal professional discussion of the matter, but I find that I am to have the field somewhat to myself and to talk to more people than I had anticipated. I know, however, that you are all interested in the subject as well as I, but I have not prepared any formal address and shall confine myself, therefore, to general remarks as to the present aspect of the important question of the future water supply of this city.

The subject is not new. I think my friend, the President, will admit that it was an old one in his early days, and it has so continued to the present. Agitation of the subject has continued for a generation past without definite conclusions being reached although we are approaching more and more closely to the necessity for reaching a decision. This futility of discussion has resulted mainly from the

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* Abstract of remarks presented at the Stated Meeting of the Franklin Institute, held Wednesday, April 15th, 1885.

absence of full and accurate investigation of the real facts upon which alone a reliable and final judgment can be made. The situation is about this: Philadelphia is a city happily situated in many respects, with a great river on either side; one stream, the Schuylkill, drains a mountain region and has been looked to both to supply the water needed for municipal purposes, and even to furnish the power by which that supply should be pumped and delivered to the citizens. Hence the construction of those early water works at Fairmount, originally breast wheels, which were later converted into turbines and which have continued in service to the present day. With the growth of the city came the necessity for an increase of quantity, and from time to time the appliances for augmenting the daily pumpage have been multiplied until now there are no fewer than eleven engines at four great pumping stations drawing from the Schuylkill river into which, to a considerable extent, the waste matters of the valley are poured. On the other side of the city is a great tidal stream which receives the waste matters of the community, and at two points upon the Delaware we have been drawing these waters to supply the districts of Kensington and Frankford, but it has long been recognized that the water pumped at Kensington contained matters prejudicial to health, and the quantity of this was increasing year by year; this station has therefore been abandoned. The serious thought of those who from time to time have been charged with or interested in this vital matter of Water Supply have been turned to the consideration of the means of amending the defects of quality and quantity. There are two sources whence the city of Philadelphia can take its water, I mean practical sources as determined by engineering considerations; namely, the valley of the Schuylkill and the valley of the Delaware. The problem to be solved is whence a suitable supply both in quality and quantity can be derived to the best advantage; namely, at the lowest cost of construction and the lowest future cost of maintenance. A gravity supply is advantageous when practicable, for the reason that the water intercepted at a sufficient elevation will pass from its source to the city through the conduits, as water will flow down hill, whereas the raising of the large quantity of water required for the supply of the city involves heavy expenditure for machinery, and a constant annual charge for fuel and service.

For two years past the Department with which I have the honor to be connected, has assiduously sought to gather all the information

bearing upon this matter which was attainable by topographical and hydrographical surveys, by meteorological observations, by chemical analyses and by sanitary iuspections, endeavoring to cover the entire field within which lay facts pertinent and important. Our observations are drawing to a close. About nine-tenths of the field of exploration have been covered, and I trust that within another year we shall be enabled to complete and digest the information so gathered and present to the city, and to the engineering world the results of our labor in complete shape. It was for lack of this information that previous investigations have been rendered futile. The most important report which has been made upon this subject was presented about ten yeears ago, in 1875, when in anticipation of the celebration of the Centennial, a commission of eminent engineers was gathered to consider the entire subject, taking into account both the condition of the present supply and what should be done for the future. That their report, containing most valuable information, should have resulted in inaction is largely attributable to the fact that they were without the necessary exact data for final judgment. They made the best recommendations which, under the circumstances, could have been formulated, but in the light of fuller information it is neceasary to differ in some respects from the preliminary conclusion which they reached.

At present I cannot say that I am prepared to announce final conclusions as to the general solution, but it appears to lie in the choice of two projects.

Many years ago Mr. Birkinbine, who was then the Chief Engineer of the Water Department, proposed to secure a suitable gravity supply by impounding the waters of the Perkiomen Creek, the most important affluent of the Schuylkill river, which, from the supposed ample flow and purity of its drainage promised to be satisfactory and sufficient. The project contemplated the construction of a high dam near Schwencksville where the valley was narrowed and the rocky banks afforded a suitable site for a construction of this kind, and the Commission of 1875 were inclined, upon the data at their disposal, to favor this project, especially as the estimates of cost of a supply from the Delaware were vastly greater. Were we sure of ample amount and good quality, the Perkiomen project would present undoubted advantages of a high order. Unfortunately our investigations tend to show that the flow of the stream, even aided by gathering the waters of some of its affluents, is insufficient for the total quantity that Phila-

delphia will require in the near future. The Delaware project had never been carefully investigated, and for this reason: in 1883 two parties were formed, one to run a conduit line to the Perkiomen and elaborate the necessary information; the second party to run a corresponding line northward to the Delaware with the view of extending the investigation to near the Water Gap, at some elevation which should be found sufficient to permit the river to flow into the conduit and thence into the city, and the apparent probability of the insufficiency of the Perkiomen gave greater weight to the Delaware project than it had hitherto borne.

In considering the route toward the Gap, an examination of the map showed that an elevated region, designated as the South Mountain, stretching from northeast to southwest, lay across the Peninsula between the two rivers and would bar the construction of an aqueduct without extensive tunneling. A line northward from the city to the Delaware river reaches that stream at a point just below the gorge of the South Mountain, and a practicable conduit line upward could thence be made by following the valley of the stream, and thus evade the formidable obstruction which the mountain presents. Pursuing this plan, the surveyors were pleased to find, in the first place, an unexpectedly favorable line to the Delaware at Point Pleasant, halfway between Trenton and Easton, and the analysis of the water of the Delaware at this point further proved that in quality it was little inferior to the noted waters of the Gap itself.

This was our discovery. Furthermore, in proceeding northward from Philadelphia the conduit line crosses the valleys of several creeks of considerable volume—the Perkiomen, the two Neshaminies and the Tohickon—the latter stream discharging into the Delaware at Point Pleasant. The thought at once suggested itself that by utilizing the flow of these streams they could be intercepted, turned into the conduit and sent to the city by gravity, and that for a greater portion of the year the flow of these would be sufficient to supply all requirements, and that for such time as this flow should be deficient it could be made up by pumping from the Delaware itself. This, practically, constitutes a new project as compared with that of drawing water from the Gap entirely by gravity, and the expense of this construction was moderate enough to bear comparison with the Perkiomen project. It was found, for example, that the distance, in each case, was about the same, namely, thirty miles, and that the cost of construction was also

about the same, namely from $6,500,000 to $7,000,000. This estimate, you will understand, is that of the cost of the construction of the conduit merely, without adding other items (which will no doubt be large), for dams, land damages and other contingent expenses.

These conduits, I might say, are designed to be twelve feet in diameter with a grade of one foot in six thousand and with a capacity of delivering to the city 210,000,000 gallons a day at an elevation of 166 feet above city datum. This elevation is that of the existing Wentz Farm Reservoir, on the county line northwest from Bridesburg, and of the proposed Cambria Reservoir in the upper portion of the Twenty-eighth Ward.

With regard to this question of quantity, the following considerations present themselves: Our present pumpage is about 70,000,000 gallons a day, with a population approximating closely to a million people. A generation hence Philadelphia will contain two millions of inhabitants. The supply must therefore be doubled which would make it about 150,000,000 gallons a day. Furthermore, allowance must be made for the fact that in a large community like ours the use of water for the multiplied purposes of manufacturing and domestic uses increases in a greater ratio than the population itself. With works of the magnitude and cost of these which we have been discussing, it would be folly to project for a smaller supply than will be required within a generation, and for this reason 200,000,000 or 210,000,000 gallons were estimated for and the dimensions and grade of the conduit were thence determined.

Going back now to the question of distance and cost it will be seen that exact observation proves that for the first time the two projects, the Perkiomen and the Delaware, began to balance each other, and should the Perkiomen prove insufficient the Delaware project would practically stand alone; but in order that all possible ground should be explored I directed the examination of the upper Lehigh, a stream with which I was personally familiar from frequent journeys over the mountains to the Susquehanna Valley, and which, although so distant, possessed favorable characteristics from the purity of its water and the great elevation of its water shed. When, therefore, the Perkiomen proved of doubtful adequacy, the acute suggestion was made by Mr. Hering, who in a most thorough and capable manner has had immediate charge of these serveys, that were a sufficient amount of the waters of

the upper Lehigh brought into the upper valley of the Perkiomen a most excellent supply could thereby be secured.

You will observe that in all this matter the question of quantity has been of vital importance. We want 210,000,000 gallons a day. Now the low-water flow of the Delaware at the Water Gap in 1883 at a time when the stream was lower than it had been within the memory of the oldest inhabitant, was gauged and its flow at that time found to be about 700,000,000 gallons of most excellent quality. At Point Pleasant the volume of the river is about one-third greater than this, and in quality nearly as good as at the Gap. The Lehigh has a moderate flow. Its minimum in 1883 being about 70,000,000 gallons, but with excellent facilities for storing water at a great elevation above the reach of pollution. The bringing of this down into the upper valley of the Perkiomen would double its supply and the combination would once more have the prestige of a practicable and promising project.

At present, therefore, these two projects lie before us for consideration and ultimate decision, and, as I said before, within another year I trust that the problem will have been solved.

It may be of interest to explain how it happens that with the Schuylkill flowing past our doors all the engineers who have studied this subject seem to have concluded that at some time or other the Schuylkill River itself must be abandoned as a source of water supply. The reasons are these: The origin of the Schuylkill is in the mountains among the coal mines. The drainage from the coal measures, supplemented by the large amount of pumping from these mines constitutes a volume of acid water which fills the upper portions of the stream and is unfit either for drinking or manufacturing purposes, or even to sustain life. No fish can exist in it, nor can human beings drink it. In the course of its flow downward the Schuylkill above Reading traverses a geological belt of limestone whence considerable affluents feed the river, bringing with them a solution of the lime and the alkaline waters mingling with the acid waters of the parent stream neutralize each other and become again fit for ordinary purposes and for the existence of fish. Thereafter we have no further difficulty in this respect; that is with regard to the chemical characteristics of the water. The water as it reaches Fairmount Dam is sometimes slightly acid, sometimes slightly alkiline and sometimes neutral. But the important fact remains to be noted that the valley through its length is a populated district from end to end, and into it are poured all the waste matters of a large and busy

population; every town and industry contributing its quota of pollution, whether sewage or the waste products of manufacturing establishments. With two great railroads extending up its banks and with communities and towns increasing year by year in number and population, the Schuylkill can be described only as an industrial valley which in the future will be densely populated, and it becomes manifest at once that unless extensive engineering constructions be planned, strict legislative enactments be passed and rigid enforcement of these laws be insured, the waters of the Schuylkill must continue to receive deleterious matters in constantly increasing quantities, and that ultimately they will cease to be available for the purposes of that great city which lies at its mouth and absorbs the contaminations of everything above.

The population of the valley above Philadelphia, at present, is in excess of 350,000, and if we are to endeavor to protect the stream from this pollution, which is not only nauseous in contemplation, but in fact dangerous to health, sewers must be built upon both banks which shall intercept and discharge all waste matters and convey them down the entire length of the valley until they can be discharged into the Delaware River below the city.

Another important fact must be observed; within sixty years a marked diminution has taken place in the minimum flow of the stream.

Sixty years ago the summer flow of the Schuylkill was estimated at 500,000,000 gallons a day. Successive estimations of the low-water flow were made from time to time, all showing a diminution in quantity until that in 1874 determined the minimum flow as 250,000,000 gallons.

Here, then, within this period the low-water flow of the stream had decreased one-half, and, supposing that it had gone no further than was observed at the last examination, the flow of the stream when at its low stage is little more than the city will require a generation hence. It follows that with but a slight shrinkage comparatively, in the future the city would be pumping up the entire river. I do not wish to be misunderstood with regard to this, and therefore beg to explain what I mean by the minimum flow: It is not probable that the total annual flow of the Schuylkill has decreased. This flow is dependent upon the rainfall, and cannot in the absence of any marked changes in the rainfall be itself materially modified, but the destruction of the forests in its head-waters, the clearing and cultivation of lands, have to a great extent deprived the river of that power of conservation which belongs

to wood land, whereby the rainfall is held back and checked, as it were, in its passage to the stream, and the flow is more nearly equalized and prevented from dashing down and passing out. With the removal of the forests this fact ensues: The rainfall rapidly descends to the stream, creating a freshet which sweeps down the valley and passes out and is lost. During periods of drought, the rains being suspended the river shrinks, its flow becomes moderate and its movement gentle, and presently we attain the minimum discharge.

In depending upon a stream, without taking means to restrain the passage of freshets, it is manifest that we can pump no more from the river than it will daily bring to us, and the minimum flow therefore should be as carefully investigated as we would investigate the strength of the weakest link in a chain from which we intend to support a weight.

It would be possible by means of dams across the stream to impound some portion of the volume of these successive freshets until the periods of drought, which occur always in summer and frequently in winter, and to draw upon these reservoirs when required. But again that question of the pollution of the stream comes in, occasioning doubt as to whether should this be done, it might not be found in the end that large expenditures had been wasted by reason of the inferior quality of the water and the injudiciousness, of depending in perpetuity upon it. For the reasons given the water varies greatly from time to time in its chemical character, potability and wholesomeness. At times during the passage, for example, of the freshets the waters of the stream being largely the results of recent rainfall, are in good condition; at other times they are highly charged with pollution and occasionally get themselves into a condition of the most nauseous offensiveness. It is manifest that unless these difficulties can be amended the Schuylkill cannot continue to be regarded as a suitable supply for a population like this, and the vital importance to modern communities of a bountiful supply of wholesome water for all purposes is so great as to constitute one of the most serious problems relating to municipal existence, and sooner or later there is not a city in the world that has not this important matter to decide.

I have endeavored to present to you briefly the aspects of the problem precisely as they present themselves to-day. It is one in which every individual is in the highest degree interested. It is one upon which the future prosperity and welfare of this city depend.

I am very much obliged to you for your attention, and trust that some one will take up the discussion at this point.

DISCUSSION.

PROF. HOUSTON.—The exceedingly interesting remarks the gentleman has just made are enough to give thoughtful people considerable matter for reflection. The question of the water supply of any great city must always be a difficult one to solve, since as the needs for an increased amount of water grow, the ability of the ordinary means to give a large supply of pure water decrease. The rivers of any country are the natural sewers into which the dirt and filth of that country drain; and to safely take the water supply of a large city from any river requires considerable thought and skill.

The problem as to the water supply of the city of Philadelphia is one to which we have all given considerable attention. A number of years ago, I called the attention of the Franklin Institute to what I regarded as a dangerous pollution of the Schuylkill River; and I am glad to hear Col. Ludlow speak in such plain and unmistakable language concerning the probabilities of the near future of the Schuylkill. I take it that the real danger coming from drinking Schuylkill water does not exist with equal gravity all the year. During a large part of the year the lower basin of the Schuylkill, from which most of our city's supply is taken, is practically in the condition of a "steppe-lake," that is a river without an outlet.

Under these conditions, its impurity increases from the loss of pure water by evaporation. For many months in the year, the citizens of Philadelphia know that comparatively little or no water goes over the dam, and were it not for the water which goes through the locks, there would be no discharge at all except that which is pumped into our reservoirs. Under these conditions, we are actually damming up the river and drinking its contents. During many months in the year, and particularly those months when we should be the most careful of the purity of our drinking water, we are drinking something that is far from wholesome. I have not the slightest hesitation in expressing this as my opinion. During this time of the year, from a water itself impure, we pass off a large quantity of pure water by evaporation, and drink the dregs. Now we do not want the dregs of the Schuylkill, especially when in the immediate neighborhood of our pumping stations we have the outlets of sewers.

Of course, Schuylkill water cannot be as poisonous as many allege, else we would not be here. The main point, in my mind, is: Can we rely on the Schuylkill for our water supply in the near future, say for the next fifteen or twenty years? Col. Ludlow has stated the problem very clearly. The very conditions of the valley of the Schuylkill seems to render it improbable that we can continue using the water for drinking purposes.

The destruction of the forests over the upper basin of the Schuylkill, unquestionably favors the rapid drainage of the rain water; so that, for a considerable part of the year, we have so limited a supply that, as has already been shown, we endeavor to drink the entire river. Unfortunately, too, during that time in the year when the rain water would make the river comparatively wholesome, by diluting it with pure water, the rapid drainage brings down the filth and sewage accumulations from the river banks. So the very time we ought to get comparatively pure water, we get it very impure. You are probably aware of the fact that when the water looks the dirtiest, it is not necessarily at its worst. In this condition it is often less harmful then than when quite clear.

I therefore thoroughly agree with the speaker that the Schuylkill cannot be relied on for our future water supply; nor to my mind can any simply impounded basin be relied on for the water supply of Philadelphia. We have in any impounded basin the very conditions going on to which I have alluded in speaking of the lower Schuylkill. If you dam up a stream and let even pure water run into it, there will be discharged into the air, as vapor, pure water and comparatively impure water will be left in the reservoir. I believe it has been the experience of almost all our large cities that have tried the impounding plan that it does not give satisfaction; not only from the disagreeable cucumber odor given to the water, but from other reasons.

The Schuylkill must undoubtedly for many years to come be looked upon as the source of our city's water supply; but, looking beyond this time, can we safely, for the next three or four generations, derive our water from this river? Were this river all we could get, of course we must go to it. That settles the question. I do not, however, believe so. It has sometimes seemed to me not such a very wild or visionary scheme to go to some magnificent natural subsidence reservoir like any of our great lakes. I know the distance is very great, but so is the population along the Atlantic seaboard. If some

plan could be devised by which our large cities could share the expense, then it does not seem to me so impracticable to look to the great lakes for our water supply.

We have other waters than the Schuylkill, however, close at hand. It is indeed a very fortunate circumstance if, as Col. Ludlow has remarked, the upper sources of the Delaware will probably, from their character, never for a long time to come be improved or cultivated. If no mineral deposits that would lead to extensive mining operations be discovered in the upper basin of the Delaware, then we may perhaps rely on the Delaware for our future water supply. But even here does not the same old question still suggest itself? Will not, in the remote future, the valley of the Delaware become densely populated and thus pollute this stream?

There is one thing which to my mind seems somewhat of a danger, and that is the discharge of the Intercepting Sewer into the Schuylkill immediately below the dam. There is scarcely opportunity for the suspended solids to do anything but settle immediately in the bed of the river. I am aware that the discharge of the sewer at this point is but a temporary expedient; but I fear we are going to permit a temporary expedient to bring a great deal of trouble on Philadelphia; a trouble that may cost much to remove.

Already some of the best sections of our city discharge their sewage into the river below the height of mean tide. On the rising of the tides the water backs up the sewer and causes a dangerous leakage of sewer gas into the houses; added to this, the prevalent southwest wind brings very unpleasant odors as it is from the lower Schuylkill; so that if we add to these sources of danger, that arising from the formation of sewage deposits in the Schuylkill at this point, the danger may become very grave. It does seem to me that this is something that we ought to be very careful about—spend a little more money if necessary—and carry the discharge a little farther below the mouth of the dam.

We have only to look at the forebay of the Fairmount Water Works to see the possibility of sediment collecting to the depth of several feet, right alongside of the inlets to the water wheels. Here, despite the velocity caused by a fall of many feet to the wheels, some six or eight feet of sediment had collected. I think there is a very great danger from similar deposits of sewage from the Intercepting Sewer, and one that ought to be attended to.

MR. GRAFF.—I hoped to have this matter thoroughly discussed among the audience present to-night. Many of them have studied it to some extent and have come to it with new light. We may sometimes look so long at an object (which is really true of painters and artists) that we lose its true proportions and have to leave it and come back to it again before we are able to see its full merit. I may probably be in that position; therefore, I feel that there may be parties here who might look on and discusss this matter with new light. I think there may be one thing said, and that is the point to which Col. Ludlow has referred: the fact that until the period when he was enabled by action of Councils to take up the matter there had never been suitable surveys made such as would enable the citizens of Philadelphia or the engineers employed to come to any positive conclusion in regard to the proper future supply of the city of Philadelphia. I am glad to say that these surveys have now been carried on for some length of time; not only have been carried on, but with the utmost care and with all the light and science that can be brought to the subject. Probably many of you realize how much there is to be considered. The developments of the day have taught us all very much more than we knew in former years; and the questions that attach themselves to this subject are so numerous and varied that it would be tiring you to go into them to-night. There are not only the surveys of the country; there are other objects besides that. We are only learning now how much of the rainfall can be utilized from a given area of county and how pure it will come to us when we get it. That matter is made variable by the condition of the country, particularly the wooded condition, the effect of cutting off the timber of the forests and all such matters. Col. Ludlow has shown you by demonstration that the Schuylkill river is now suffering from reduced volume produced by that cause. Therefore it behooves us all, and particularly those interested in the subject, to study thoroughly what may be the effect upon the Delaware and other streams suggested. Continued studies of these points have to be made when considering such a subject as this. They are now being considered. The geology and the surveys of the county examined have been so thoroughly gone over by Col. Ludlow that they are resorted to, and as far as they go, will be used for the geological surveys of the State; this is to show how thoroughly the surveys are being made. I agree with Col. Ludlow, that at this stage of the matter, it

would not be proper for any engineer to say positively what shall be the supply of the city in the future.

It is only feeling our way just yet That way has been felt very far, and probably very soon an opinion, perhaps a very accurate one, can be formed. I shall be willing to leave the matter in the hands of the Chief Engineer until these surveys have been completed and the whole subject thoroughly studied up. The balances that he tells you about of all the different plans investigated can then be made very important, but can hardly be gotten at until the surveys are completed. In the meanwhile, do what we may, we have to resort to the Schuylkill for our supply, because any comprehensive plan of supply is a work which will occupy much time. Even if we were to-day prepared to say that the Delaware is the proper source of future supply and the building of an aqueduct were determined upon to-morrow, the difficulty of getting from the State appropriations necessary to carry on such a work is so great that a number of years would elapse before it could be brought into use. Therefore, in the interim, we are obliged to do the very best that we can with the supply we get now. Prof. Houston has said, very properly indeed, that the Schuylkill has the disadvantage of being bottled up in Fairmount pool in the summer months, when the water is low and the outlets are only through the wheels at Fairmount and the locks, because at that time the pumping there has to stop and steam power take its place. Therefore the ability of the stream to purge itself from impurities is reduced just at the time when you want it to be the most pure. Another point comes in with that consideration, and that is, to-day we cannot store sufficient water in our reservoirs to give it the possibility of subsiding in any way. I think I am right in saying that the maximum storage in summer in the reservoirs is scarcely two days of the whole supply. Therefore, any discontinuance of pumping, you will necessarily see must reduce the reservoirs to so low a point as to make it very unsafe. The reservoirs are so small that the water may be said to simply go through them—in one side and out the other. No time can possibly be allowed for subsidence, whilst the storage capacity is so limited. As we have to continue using the Schuylkill the palliation, not an entire remedy, is the erection of larger reservoirs, a relief which I hope soon will have some attention. The subject of making an appropriation is now before the Legislature and possibly something will be done with it. The subject of the purity of the water in the Schuylkill (the impurity, I

should say), is one there can be no kind of doubt about. At times it is measurably pure, at others it is not so. There is no use of disguising the fact. As I said before, a little palliation might be made by ability to store water. The subject of any relief of the Schuylkill, I think, has been pretty well gone over by the Chief Engineer. It is a very serious point; when you come in any way to disturb the industries upon the Schuylkill valley, of course there will be more or less difficulties; such difficulties the Colonel has encountered, and has to a certain extent met. Protection may be insured by the sewer now building to carry the impurities below the point of supply. After all the matter comes down to obtaining the light necessary to form an early decision as to what shall be the future supply. I think the surveys now making will give us this light, and with the head we have conducting them, we are likely soon to come to a conclusion on that important point.

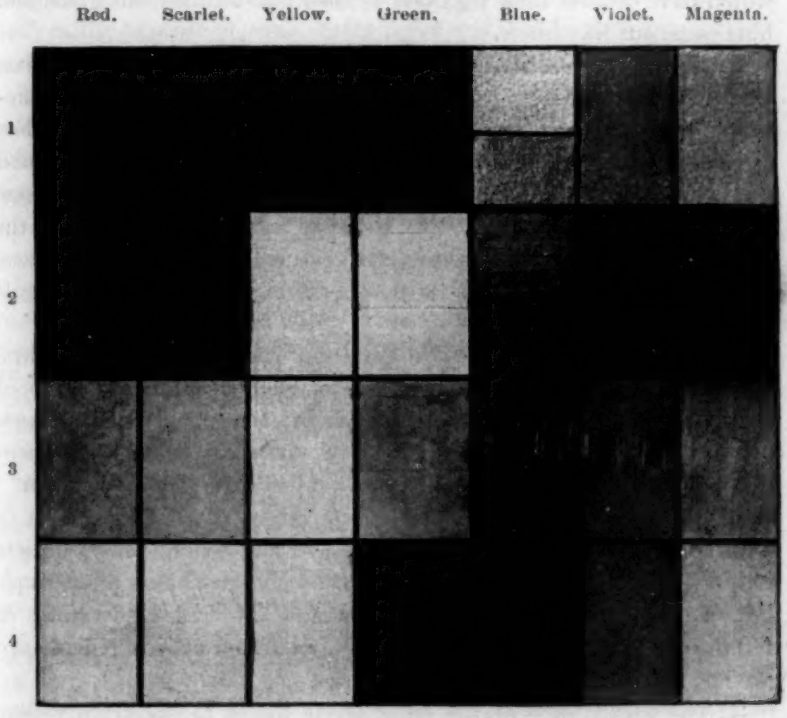
COLORED CORONA.—Cornu notices several interesting particulars in the late phenomena of colored illuminations surrounding the sun. The reddish corona, concentric with the sun, observed by Thollon and Forel, is the simplest manifestation; it appears in perfect form only when the sun is at a great height above the horizon in the midst of a sufficiently clear sky. When the sun declines, the lower arc of the corona enlarges and becomes more intense; underneath from the horizon springs a colored band of the same tint which extends toward the corona as if attracted by it and finally surrounds it. During this change the brilliant interior space of a slightly bluish whiteness remains sensibly circular, but by an optical illusion the sun seems to be drawn toward the lower border. Towards sunset the tints gradually change first to a Naples yellow then to a brownish yellow. After sunset the corona puts on the appearance of a light smoke which gradually fades away, the colors blending with those of the setting sun. Mist or light cirrus generally effaces all these phenomena; but thick cumulus with openings of blue sky is sometimes attended with a bright copper-red, shading through various intermediate tints into the azure of the sky. The corona introduces a great perturbation in the polarization of the sky, varying the distances of Arago's, Babinet's and Brewster's neutral points from the solar or antisolar centres and is attended by four new neutral points placed in pairs nearly at the height of the solar and antisolar centres.—*Comptes Rendus*, Sept. 22, 1884. C.

THE OLDEST EUROPEAN CITIES.—The oldest city in Europe is Argos, in Greece, founded about 1850 years before the Christian era. Next in order are Athens and Thebes, in Greece; Cadiz, in Spain; Cumæ, Syracuse, Locri, Rome, Crotona, in Italy; Saguntum, in Spain; Bysantium; and lastly Marseilles, which was founded 580 B. C.—*Les Mondes*, Sept. 27, 1884.

ISOCHROMATIC PHOTOGRAPHY.*

By Fred. E. Ives.

For the purpose of better illustrating the capabilities of my process of Isochromatic Photography, I have recently made a large number of photographs of a color-scale, which is made up of pieces of woolen cloth, dyed red, scarlet, yellow, green, blue, violet, magenta, etc. The exposures were made through color-screens, which were carefully selected by the aid of the spectroscope, in order that it might be known in each case what kind of light was transmitted.



I have not had time to make a set of lantern positives, but will show some of the negatives on the screen, and also one positive, made from prints which have been arranged for comparison.

* Read at the Stated Meeting of the Institute, Wednesday, May 19, 1885.

The first negative is an ordinary photograph of the color-scale, in which blue, violet and magenta are the only colors which photograph with considerable intensity.

The second photograph was made with an eosine-stained plate, exposed through a yellow screen. Light blue, green, yellow and light yellow-brown are the only colors which photograph well.

The third photograph is by my isochromatic process, and all of the colors come up in approximately the true proportions of their brightness.

The fourth is one of my chlorophyll plates exposed through a scarlet screen, and brings out with remarkable intensity all those colors which have usually been regarded as most non-actinic; but green and blue come out like black.

In the lantern positive, seven squares are shown from each negative, arranged for comparison. The first row is from the ordinary photograph, the second is from the eosine plate exposed through a yellow screen, the third is from the isochromatic photograph, and the fourth from the chlorophyll plate exposed through the scarlet screen. These photographs tell their own story so far as regards the capacity of the processes; but my investigations have revealed some remarkable facts, which I will now state briefly, without entering further into the details of my experiments:

1. Although collodio-bromide emulsion plates, stained with blue-myrtle chlorophyll alone are capable of photographing all colored objects in the true proportions of their brightness, they are far more sensitive to the extreme dark red of the spectrum, below the absorption band of chlorophyll, than to either the orange, yellow or green.

2. All red, orange and yellow objects reflect the dark red light to which chlorophyll plates are so sensitive, and bright yellow objects reflect as much of this light as red ones. Yellow objects photograph lighter than red ones by this process, because they reflect two kinds of light to which the plates are sensitive, while red objects reflect only the one kind.

3. The sensitiveness of the chlorophyll plates to spectrum yellow and green may be greatly increased by treating them with the tea organifier, which also nearly doubles the general sensitiveness, but without appearing to alter the effect in photographs made through a yellow screen. If a green screen is used, of a shade which does not transmit the dark red of the spectrum, the resulting photograph is

better when the tea organifier has been used, and does not then differ in any respect from one made by exposing an eosine-stained plate through the same screen.

4. The dark red of the spectrum passes freely through a solution of chlorophyll, and through ruby and orange glass, but is absorbed by common green glass, or by solutions of sulphate of copper or Prussian blue.

These facts show that plates prepared with both sensitizers, according to my original instructions, are, strictly speaking, more nearly isochromatic than those prepared with chlorophyll alone; but that in the production of photographs of colored objects they seldom offer any practical advantage, except that of reducing the exposure about one-half, at the expense of some extra labor and care in their preparation and development.

It is also evident that the safest light in which to prepare and develop chlorophyll plates is neither ruby nor orange. The light which I find most suitable for this purpose is that transmitted by a combination of two thicknesses of deep orange glass with one of green.

SECULAR VARIATIONS OF MAGNETISM.—Duponchel discusses the normal component of æthereal undulations which produces gravitation, and the tangential component which is manifested by heat, light, electricity, etc. The tangential undulations are of two kinds: a spherical wave of rotation with maximum intensity at the equator, and a cylindrical wave of rotation with a variable grand circle base, normal to the trajectory. The combination of these two waves gives rise to an equator and poles of energy which may be deviated by perturbations in the direction and velocity of translation. Each planetary body, in addition to its own poles and equator, has a secondary system resulting from the induction of the solar equator and poles, and subject to modifications of solar movement by planetary actions. These actions are of two kinds, one in an inverse ratio to the distance, due to planetary eccentricity, and one proportional to the distance, resulting from the sun's orbit around the centre of gravity of the solar system. The first is especially sensible in the case of Mercury, which, from its proximity and its great eccentricity, produces four annual undulations, which are clearly discernible in the curves of sun spots and of terrestrial temperatures. The two actions are combined and mutually re-enforced for Jupiter, while they are nearly neutralized for Saturn. From the secular variations of magnetism which are brought about by these combined actions, Duponchel infers the existence of an unknown planet, with a period of about 467 years, which is now traversing the constellation Capricornus.—*Les Mondes*, Nov. 1, 1884. C.

On the THEORY of the FINANCE of LUBRICATION, And on the VALUATION of LUBRICANTS by CONSUMERS.*

By Robert H. Thurston, Hoboken, N. J.

It is proposed by the writer, in the following paper, to consider the errors of the customary methods of finance, in their relation to the subject of lubrications, to exhibit the correct theory of such finance, as it appears to him, and, finally, to show what is the proper method of valuation of lubricants. The singular and important losses which often arise from the common system of purchase, application, and valuation of the various unguents, will be exhibited, and illustrations will be presented, both of the present and of the proposed systems.

This subject was first studied by the writer some years ago, and it was shown, in a work published at that time,† that very serious losses may follow the application of lubricants to machinery with no other guide to economy than the relation of their market-prices and their friction-reducting power and endurance, under the given conditions of use. The equations here presented were, in most cases, subsequently developed in illustration of the principles outlined in that work, and were first presented for publication in a paper read before the American Society of Civil Engineers, as a portion of a discussion at a recent date.‡ The whole subject has also been traversed in the later work of the writer on the subject of friction and machinery,§ in which a chapter is devoted to the matter of finance in this connection. The following paper is intended to give a more detailed exposition of the subject than has hitherto appeared, and to present a larger collection of facts and data than could properly be given in the later work. A large proportion of this information also was not available at the earlier dates.

The writer is under obligations to Messrs. C. J. H. Woodbury, J. C. Hoadley, and T. N. Ely, for information which they only could

* Read at the Atlantic City Meeting of the American Society of Mechanical Engineers, May 25, 1885.

† "Friction and Lubrication." New York, 1879.

‡ "On the Real Value of Lubricants," etc., Jan. 7th, 1885; Trans. Vol. XIII, p. 476.

§ "Friction and Lost Work in Machinery and Mill-Work," New York, 1885.

satisfactorily supply. as well as to a number of other gentlemen who have kindly contri. uted facts and figures of great interest in this connection.

The Cause of Lost Work, in machinery, will be found, on the most casual examination, whatever the kind of mechanism, to be due, in every instance of well-designed and properly managed apparatus, to the friction of parts moving in contact and under pressure. Further examination will show that it is the almost universal custom to endeavor to reduce this waste of energy to a minimum, by the use of lubricants which are interposed between the rubbing surfaces. The inference at once follows that the unguents form a class of materials the importance of which can hardly be overestimated. The efficiency of these substances, and their value in the market, thus become matters of supreme importance, since the efficiency of the lubricant determines to what extent it is possible to reduce such losses of work and enegy, and the price determines to what extent this is commercially allowable, and the cost of such economy of work and power. There is evidently some relation of price, efficiency of unguent, and value of work saved or wasted, which will determine just what lubricant may be best used. It is evident that the relation of either two of these quantities does not indicate which is the proper lubricant, or give the real value to the consumer of that which he may select for use.

It is obvious that the real value of any friction-reducing material has no necessary or direct relation to its market price, except in so far as that price comes in to determine the financial aspect of the question which arises when it is necesary to choose which of any number of available materials is, on the whole, best for a specified case. Its real value is actually dependent, not only upon its own intrinsic properties, but also upon the value of the power which is to be saved by its application. Its value to the consumer is thus dependent upon economical conditions entirely apart from those of its production by the vender—conditions which include all which influence the total cost of the power saved or wasted, indirectly, as well as directly.

The losses due to this friction of the working parts of machinery include vastly more than the mere loss of power in overcoming that friction. They involve, often, an enormously greater amount of expense in the meeting of incidental losses, in the wear and repair of bearings and of journals, in the expenses arising from accidents traceable, more or less directly, to the frictions of working parts, and in

other less easily determined losses. Fires are sometimes caused by the use of improper lubricants, or by inefficient lubrication; costly steam engines, and other machinery, have been ruined by "break-downs" in consequence of the excessive friction and abrasion caused by the use of such unguents; and fine mechanism is often seriously injured by the change of form and the "cutting" so produced.

The common system of valuation of lubricants, and of purchase, if it can be considered a system, consists simply in a comparison of the market price of the available kinds with their friction-reducing power and their endurance, where these qualities are known. Even these essential quantities are seldom determined with any degree of accuracy, and the buyer is compelled to take what he can find, try it upon his machinery, and if it produces no perceptible ill effect, to purchase at the best rates which he can obtain, and without being able to ascertain to what extent he is the gainer or loser by changing from one kind to another. It is usually assumed that of two oils having prices proportional to their endurance, or to their friction-reducing power, the purchaser may take either with practically equally satisfactory commercial or financial results. The advisability of purchasing is considered to be settled by this comparison. No comparison is made between the costs of wasted power and the expense of purchase of lubricants, as a rule, even by the most experienced buyers. It is perfectly obvious that such a system must be absolutely wrong, as must any method which does not take into account every item of profit and loss dependent upon the use of the unguent, and which does not thus make it possible to make up a balance-sheet including all such items. The real question is not whether the difference in the price of any two oils is justified by the difference in their intrinsic qualities, but whether the profit to be made in the purchase of the one, rather than the other, is not more than compensated by the cost of the difference in power, and in running expenses, produced in the mill, or the shop, or on the railway train, by such substitution. If a dollar expended for oil may be made to show a profit of 25 per cent., in any given case of a change of lubricant, as represented on the books of the purchaser, it by no means follows that he has gained by the operation. It is very likely to be—and, indeed, is often—the fact, that a comparison of the total running expenses of the establishment will show that this apparent profit has been made by the production of an actual net loss, in cost of power and other expenses, vastly exceeding the saving in purchase-money.

To make the change advisable, it is evidently necessary that the total cost of operating the establishment must be reduced permanently, or so long as the new oil is used, by the subtitution of the latter for that formerly in use. To determine whether the change is profitable, therefore, it is necessary to ascertain just what are the items of expense affected, and to what extent the proposed change will alter their total amount. The total expense to be charged to the friction of machinery consists of the following items, as principals, and probably of minor and less easily determined expenses:

(1.) The cost of power produced, only to be wasted by that friction.

(2.) The expenses incurred in wear and tear of running parts, and in the replacement of parts destroyed, either by direct strains or by gradual wear due to such exceptional ressistances as are the effect of excessive friction.

(3.) The casual, the indirect, and often unperceived, yet none the less serious, losses throughout the system which are not included in the above.

(4.) The cost of the lubricating materials applied for the purpose of ameliorating these losses.

The first item includes a part of the expense of the prime mover, such as cost of fuel and oil used on the motor, interest on the capital invested in the machine, and in the machinery of transmission, wages paid engineer and firemen, or other attendants, insurance and taxes upon that part of the plant, including so much of the building as is properly chargeable to the motive-power department. The second item includes costs of repair, refitting or replacement of journals and of bearings, the repair of break-downs caused by excessive friction, or by hot bearings seizing the journals, and, often, the cost of throwing out the whole machine and introducing a new one to take its place. The conditions determining the life of the machine, in fact, are what are included under this head. The third item includes the exceptional damages resulting from friction of excessive amount, and which may be more likely to occur with one oil than with another. Its amount can never be calculated with any great degree of exactness. A hot journal may cause the delay of a train, and consequently a collision involving loss of life and destruction of property; a chronometer suddenly changes its rate, in consequence of the abrasion of some dry spot on its arbors, and causes the wreck of a steamship freighted with human beings and valuable cargo; the quality of the fabrics made in a cotton

mill making fine work, because of defective lubrication, is altered by the breaking of threads, by the imperfect action of looms, or by the lubricant spotting the cloth. Such losses are experienced very frequently in manufacturing, and in every mechanical operation, and are very seldom exactly calculable. The fourth and last item is usually, it is probable, the least important of all. It is, however, one which appears most prominently, and which is, therefore, most certain to appeal directly to the mind of the interested proprietor, and to the buyer of the oil. It will be seen, later, that this is so small an item, in many instances, that it becomes absolutely unimportant, as influencing the choice of lubricant.

The differences in the magnitudes of the losses comprehended in the first three classes of expenses, as above, are enormous; those occuring in the costs of oils and greases, as effecting those expenses become utterly insignificant in comparison.

Such are the several classes of costs, the variation of all of which must be considered in any system of valuation of lubricants, and in any systematic theory of the finance of the subject. It is obvious that a gain is effected, on the whole, only when the reduction of total cost, as above measured, is reduced; and it becomes economical to buy a cheaper lubricant only when its use leads to a decrease of expense in its purchase which is not compensated by an increase in the sum of the first three items above enumerated. Where all four items are diminished, the advisability of the change is indisputable; but when, as is, probably, usually the fact, decrease in cost of lubricant implies increase of friction and loss of power, a careful balance must be struck.

Before the real value of any lubricant to the consumer can be determined, therefore, and whether any proposed change is desirable on the score of economy, it becomes necessary to ascertain the total expense chargeable to friction, in a manner already indicated, and to compare the difference of cost of unguents with the difference in costs of other items of expense produced by change of lubricant in the manner intended. In making this comparison it is first necessary to determine in what terms these expenses may be best expressed, and in what magnitude they enter the equations representing the problem.

(1.) The cost of power wasted may be expressed in the usually adopted terms, the cost in dollars per horse-power and per hour, or per year; or it may be given in foot-pounds of work, irrespective of time. The first of these methods of valuation is the more common.

This quantity varies greatly in different localities and in different establishments; its average and fair value for ordinary cases will be given be given presently.

(2.) The cost of wear and tear, and of depreciation, is an even more variable quantity than that of power. It cannot be stated definitely and generally; but it may usually be very fairly measured for any given case. An allowance is customarily made based upon the value of all machinery subject to this kind of depreciation. It will always be permissible to take this expenditure, in any establishment considered, as proportional to the power employed, and to include it thus in the first item. It will be so included in the treatment here adopted. It sometimes happens that a decrease of the total power wasted by friction is accompanied by an increase in the amount of wear: in such cases the oil producing this remarkable effect, which is usually a mineral oil, without admixture, having too little body for its work, should be rejected without further investigation.

(3.) The third item, the casual and irregular losses, should, where possible, be made a constant and regular item of charge by securing insurance against all such kinds of loss. Where this cannot be done, the proprietor should insure himself by accumulating a fund to meet this expense, assuming a rate of accumulation which experience may determine to be safe, for a series of years. This item then becomes chargeable as so much insurance, and can be introduced, with other insurances, in the first of the above divisions.

All three of the charges above described may evidently be thus brought to one method of charging, and may be entered upon the account as so much per horse-power and per hour, or per year, or per foot-pound of work if preferred.

(4.) The fourth and last item, the cost of lubricant, is measured by the charge per gallon, and by the number of gallons used per hour, or per annum, or for the specified work. This is, in every case, ascertainable by observation, or trial, either in the establishment in which it may be used, or upon the testing-machine, under precisely the conditions, if attainable, as to pressure, speed, temperature, and condition of bearing surfaces, of its application, in the shop, the mill, or on the axle of a railway train.

Having thus reduced all expenses arising from the existence of friction to one measure, the dollar, and the cost of the lubricant being expressed in similar terms, it becomes easy to solve the most vital of

the economical problems arising in this connection. These two items, thus determined, being ascertained in magnitude, for each kind of lubricant, a comparison of the totals settles the question of profit or loss. In every case, the exact value of the items being ascertained, the conclusion becomes evident and certain. It is further evident that the uncertainty arising, in any attempt to make application of these principles, comes, in every case, not from inexactness of the principles, but from the difficulty, should any exist, of determining the exact values and precise conditions.

The algebraic theory of this case is constructed very easily, and in a very simple manner, as follows:

If, in any case, U be taken as the measure of the power wasted, or of the work lost per hour or per annum, and if k' be its total cost, as above, for the unit of time, and if q be the quantity of the lubricant used in the same time and k is its cost, including its application to the journals, the total expense chargeable to friction, being called K, must be measured by

$$K = kq + k'U \tag{1}$$

But the work done is equal to the product of a constant, a, dependent upon the units employed, the value of the coefficient of friction, f, the total load, P, and the space passed over by the rubbing surfaces, S, which last is also equal to the product of the velocity of rubbing, V, and the time, t, taken as the unit of comparison. Then

$$U = afPS = afPVt \tag{2}$$

and the cost, K, thus becomes

$$K = kq + k'afPS \tag{3}$$

or,

$$K = kq + bf \tag{4}$$

in which b is a constant, in any given case, and equal to

$$b = ak'PS, \tag{5}$$

and the equation, as thus simplified, may be applied to all cases.

The value of f is to be ascertained by experiment, under the exact conditions of use, and this being determined, the total cost becomes calculable, and a satisfactory comparison may be made. That lubricant is best which, all things thus considered, gives the lowest value of K, and where wear of serious amount occurs, as may happen when using oils badly adapted to the pressure and speed, the cost of such

additional wear must be put in as an additional charge. With properly chosen oils, in regard to which, only, any doubt can arise, in the endeavor to make a selection, this may be probably usually neglected.

The value of the oil, in terms of the total cost and of cost of wasted power, is

$$k = \frac{K - bf}{q}, \tag{6}$$

which equation shows that the value is the greater as the quantity demanded is less, and that it also increases when the coefficient of friction decreases. These equations, also, show that the total cost is very nearly proportional to the coefficient of friction when, as is the usual case, the cost of lubrication is small in comparison with that of the power wasted. The value of the lubricant is then very nearly proportional to the reciprocal of the coefficient of friction, and has no necessary, or direct, relation to the market price. It will be seen, later, that this conclusion is correct, and that the price of an oil, and even the quantity consumed, are matters of little importance, as a rule, in comparison with the amount of gain or loss of power by variation of friction of moving parts due to change of unguent.

Two oils being compared, the costs of wastes are, respectively,

$$K_1 = k_1 q_1 + bf_1; \; K_2 = k_2 q_2 + bf_2, \tag{7}$$

and the saving effected by the use of the better lubricant is

$$K_1 - K_2 = k_1 q_1 - k_2 q_2 + b(f_1 - f_2). \tag{8}$$

If the saving in value of power lost is just equal to the difference in cost of lubrication, it is evident that the change will not affect the total cost, and it is a matter of indifference whether it is made or not. That is to say, if $b(f_2 - f_1) = k_1 q_1 - k_2 q_2$, we shall have $K_1 = K_2$ and profit and loss are equal. When $b(f_2 - f_1) > k_1 q_1 - k_2 q_2$, the result is evidently a gain; and when the first member of the inequality is less than the second, a loss is effected. Thus we have a criterion of the advisability of changing the lubricant in the equations:

$$K_1 = K_2; \; k_2 q_2 - k_1 q_1 = b(f_1 - f_2) \tag{9}$$

$$k_2 = \frac{k_1 q_1 - b(f_2 - f_1)}{q_2}. \tag{10}$$

If two oils are compared, therefore, it is seen that, the first having the price, k_1, giving the coefficient, f_1, when used in the quantity, q_1, the second may be profitably used in the quantity, q_2, if giving the

coefficient, f_2, only when it can be purchased below the price k_2 of equation (10), the two prices being considered as including the cost of application to the bearing and of removal. Should the oils compared have so little body that wear takes place to any appreciable extent, the cost of the wear is to be added to the cost of power, in each case.

If, in any case, as often happens, the quantity used is practically the same, whichever oil is used, $q_1 = q_2$ and the criterion becomes:

$$k_2 - k_1 = \frac{b}{q_2}(f_1 - f_2); \tag{11}$$

$$k_2 = k_1 - \frac{b}{q_2}(f_2 - f_1) \tag{12}$$

The allowable purchasing price is below the value thus obtained.

Where the same oil is used, but may be applied in greater or less quantity, we may obtain, similarly, a criterion for the quantity to be profitably used. It is evident that the advantage of increasing the quantity is to be found in the reduction of the cost of power and incidental losses. If, in any two cases, we get

$$k(q_2 - q_1) = b(f_1 - f_2) \tag{13}$$

the gain just balances the loss, and the criterion becomes

$$q_2 = q_1 + \frac{b}{k}(f_1 - f_2) \tag{14}$$

and, assuming it to be found, as is usual, that a decrease of power follows increase of freedom of supply of lubricant beyond the amount customarily given, the limit is reached at the above amount. This statement must, however, be qualified by the reminder that it is often possible to supply oil as freely as may be desired, without important loss, by the use of a good system of collection and renewal, with occasional purification. The comparison then lies as in the first cases, the costs including those of purification and replacement. As the friction of lubricated surfaces is sometimes affected to a very great extent by variation in the rate of supply, especially at high speeds of rubbing, this case becomes important. The lower the cost of the oil, in any case, and the higher the cost of power, the more freely should the unguent be supplied to the bearing.

When the relative durability and the coefficients of friction of oils proposed in any case, are known by direct experiments made under the precise conditions of intended use, it is equally easy to determine,

wear being neglected, what are their relative money values. If an oil already in use be taken as the standard, and if an oil to be compared with it is found to have e times the endurance of that standard, the quantity used should be $q_2 = \frac{q_1}{e}$. If the second oil have a coefficient of friction h times as great as the first, the work of friction will be correspondingly reduced or increased, and the cost of that work will be $bhf_1 = bf_2$. The total costs will then become

$$K_1 = k_1 q_1 + bf_1 \tag{15}$$

$$K_2 = k_2 q_2 + bhf_1 \tag{16}$$

and the criterion is obtained, as before, by making these expressions equal, whence

$$K_1 = K_2;\ k_2 = \frac{[k_1 q_1 + bf(1-h)]e}{q_1} = e k_1 + bef_1 \frac{1-h}{q_1}. \tag{17}$$

Any cost, on the journal, less than this value of k_2 is profitable; any higher cost will produce a loss. At this cost, the user will neither gain nor lose by the change of lubricant.

It is obvious that the value of b may be expressed in any convenient units of cost quite as well as in those above taken. It is usual to measure costs on railways by amounts per train-mile, as, for example, pounds per train-mile, in measuring expenditures of fuel, miles run per quart, or per gallon, in rating expenditures of oil. As has been seen, these are but a part of the total expense; but it may sometimes be convenient to obtain an approximate estimate of the relative values of lubricants, on the assumption that wear and other costs may be neglected, and the value of b is then to be expressed in the money value of fuel used per train-mile; which cost will evidently be proportional to f. The relative costs will be proportional to the values of h.

In railway practice, it is often found that the cost of wear is a very serious item, but probably only when using an oil which is unfitted for use as a lubricant, and which should never be used at all, as some of the black mineral oils. Could the lubrication be as effectively carried on as in other cases, and could the dust be perfectly excluded, the loss from this cause would become insignificant. Assuming this to be the case, we may write the equation for this case,

$$K = kq + df \tag{18}$$

in which df is the total cost of power per train-mile.

The criterion is found as before, substituting d for b, in the several equations already derived,

$$k_2 = \frac{k_1 q_1 - d(f_2 - f_1)}{q_2} \qquad (19)$$

As, in all cases, the cost of power wasted is a function of the quantity q, if the law of variation can be ascertained and expressed algebraically, the most economical rate of supply can be ascertained in making $\frac{dK}{dq} = 0$, for a minimum. Similarly, the best value of k may be determined, for the case in which the same quantity is always used, by making $\frac{dK}{dk} = 0$.*

The numerical value of the items which have been found to constitute the costs of lubrication and wasted power must be determined before application can be made of the theory of finance just developed. Among these items, the price of oil, as has been remarked, is the least important; but it is that which is most prominent, as a rule, in the view of the buyer, as well as of the seller. These prices are continually varying, and it is impossible to find values for k which may be taken at all times probably correct, or as being always fair. The real value of the figure to be assumed is, as already stated, the cost of the lubricant on the journal, and includes the cost of application, as well as the market price. The figures given below will be taken here as fair values of the unguents named, as now sold in the market. In each case, the oil is assumed to be a goed representative of its grade, such as may reasonably be expected to be obtainable in the market by any skillful and experienced buyer who may choose to secure it.

Prices of Lubricants.

Sperm oil, per gallon	$1 10	Heaviest mineral oil, per gallon	$0 75
Neats-foot, "	1 00	Medium machinery oil	50
Tallow oil, "	70	Light lubricating oil	25
Lard oil, "	70	Crude well oils	20
Greases, per lb	25	Kerosene (unrefined)	10

These figures can only be taken as illustrative. The prices obtained in the market for the machinery oils vary enormously, and without any fixed relation to their values. One maker has no spindle oil at a lower price than $0.40; while others make what they call spindle oils

* *Encyclopedia Britannica.* Art. Lubricant.

at one-half that price. Other oils and the greases, animal and vegetable, are subject to similar, but usually smaller variations of price. In one case, the maker obtains less than 15 cents per gallon for a machinery oil; while the vender of a trade-marked oil uses the same grade, buying at that price and selling at a profit of several hundred per cent.

The quantities of oil used for the various purposes of lubrication differ quite as much, where distributed by different hands, as do the prices. It may probably be estimated that at least one-half of all the power expended in the operation of the average manufacturing establishment is applied to the work of overcoming the friction of lubricated surfaces. The coefficient of friction will average a high or low figure according to the kind of machinery. The heavier the latter, the lower the friction coefficient. Light machinery gives a high value of friction, which is therefore very great on the spindles, and on the machinery generally of the textile manufactures, lower on the heavy machines of the iron-working trades, and very low, comparatively, on the axles of railway engines and cars. The range is probably from twenty down to one per cent., or even less. It will be here taken as averaging, in good practice, ten per cent. in mills, five per cent. on heavy machinery, and one per cent. on railways. The oil must evidently be selected with a view to its use, the heavier pressures and lower coefficients being necessarily obtained with heavy lubricants—oils or greases—and the lower pressures and higher coefficients being given where the lightest possible oils are properly and customarily employed, with more copious supply.

(To be Continued.)

Siliceous Bronze.—Copper, which is desirable on account of its great conducting power for electricity, cannot be employed on long circuits, on account of its great ductility. Henri Vivarez finds in siliceous bronze a conductibility comparable to that of copper, and a mechanical resistance greater than that of iron. The silicium may be introduced in various proportions, the mechanical resistance varying inversely as the conductibility, so that different qualities may be obtained, adapted to the different services which are required; thus in telegraphy, wires of galvanized iron which weigh 155 kilogrammes per kilometre, can be replaced by wires of siliceous bronze which weigh only 28 kilogrammes; in telephony iron wire of 25 kilogrammes can be replaced by wires of siliceous bronze which weigh only 8·45 kilogrammes.—*Les Mondes*, Jan. 12, 1884. C.

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

By Professor Edwin J. Houston.

No. 8.—Reis's Invention of the Articulating Telephone.

It not unfrequently happens in the history of science that some particular discovery or invention is made so far in advance of its time, as to fail to receive general public recognition. This is especially the case when the discovery or invention is of such a nature as to aim at a revolution of old ideas or methods. Deeply rooted ideas, prejudices, or habits are not easily changed, and unless the discoverer or inventor has unusual good fortune the new truth he proclaims to the world may fail of recognition. This, indeed, must be so until other minds are able to contemplate the discovery or invention from the same mental stand-point as its author.

The speaking, or articulating telephone, affords a remarkable illustration of a great invention born out of its time. When its inventor, Johann Philipp Reis, of Gelnhausen, Germany, as early as 1860–1861, produced the instrument that he named the "telephone," and claimed for it the ability to transmit musical sounds and articulate speech, the claims were received with incredulity. Even Prof. Poggendorff, editor of the *Annalen*, who might have been expected to have been better informed, went so far as to refuse to publish a written description of the instrument which Reis sent him as early as 1862. The electrical transmission of articulate speech was regarded by Poggendorff as a scientific impossibility, and it was not until the year 1864, when Reis gave a descriptive lecture of his instruments at Giessen, and exhibited the apparatus to some of the most distinguished scientific men in Germany, that Poggendorff, at last able to appreciate the labors of Reis, requested the latter to prepare a description of the same for publication in the *Annalen*. This request Reis very properly refused. Even the Physical Society of Frankfort, before whom Reis gave the first public lecture on the telephone, although it extended to the inventor the recognition of election as a member, was apparently unable to properly appreciate the importance of the discovery, and so took no further notice of the same.

Reis made various improvements on his instruments and showed

them in actual operation as transmitters and receivers of articulate speech to many parties of well-known scientific ability in Germany, some of whom are still living. His failure to impress the general public with the importance of an invention that he himself clearly saw, doubtless hastened his untimely death, which occurred at Friedrichsdorf, January 14, 1874.

Various improvements and modifications of the original apparatus of Reis were made by different inventors, but they too failed to receive general public recognition, and at the time of the announcement of Bell's telephone, especially at the time of its exhibition at the Centennial Exhibition in Philadelphia, in 1876, the researches and inventions of Reis were almost forgotten.

The times were more propitious for Bell, and his instruments were very favorably received by the scientific men who saw them at the exhibition. The fortunate circumstance of an exhibition which attracted to it the leading scientific minds of the world, gave the trials of the Bell instruments advantages that were denied to those of Reis. The enthusiasm attending this exhibition was wide spread, and Bell was hailed by many as the inventor and discoverer of a new art, while poor Reis, the true inventor and discoverer, was almost forgotten. Indeed, even at the present time, the most extravagant claims are made on Bell's behalf as the inventor of the articulating telephone, claims that are actually construed to give to Bell priority of invention in the employment of electricity for the transmission of articulate speech. A careful consideration of the claims of Reis as the first, true, and original inventor and discoverer of the articulating telephone, clearly prove the remarkable advance he had made in the art of telephony, so that at the present time the majority of scientific men discredit the claims of Bell as the discoverer of a new art, and recognize Reis as the first and true inventor, while Bell is awarded the credit of adding certain valuable improvements to the original inventions of Reis.

The public enthusiasm that attended the somewhat extravagant newspaper descriptions of Bell's first Centennial experiments has long since died away, and a careful and unbiassed examination of all the printed records of the original Reis telephone, both by the inventor himself, or by his contemporaries, leaves but little, if indeed any honest doubts, but that Reis's original instruments were intended by their inventor not only for the transmission of musical sounds, but also for the transmission of articulate speech. Reis's statements as to the pur-

pose of his invention are of the most unequivocal character, as we shall hereafter show. We find him discussing in a clear and logical manner the physical conditions requisite for the electrical transmission of speech. At first he is almost disheartened at the difficulties that must attend the construction of a single instrument that should be able to reproduce all the actions of the various organs concerned in human speech.

Starting from what had been already accomplished, as in the talking machine of Faber, he endeavored to conceive a simple mechanism that would replace the organs of the mouth and throat that are concerned in the production of articulate speech. He soon convinced himself of the futility of invention in this direction and took a step that marks a master mind. He abandoned the effort to reproduce the effects produced by the vocal organs and gave to himself the problem of how best to imitate the action of the human ear. He philosophically discusses the action of this organ in the reception of sounds, and sets about producing an instrument that can simulate such action. The outgrowth of such researches was the telephone, which, as Reis left it, contains all the essential features of the present articulating telephones in general use to-day in so many different portions of the world.

It is a curious fact, as has been pointed out by Prof. S. P. Thompson, in his book on the Telephone, that the ground gone over by Reis and Bell in the description of their several inventions is substantially the same. This, indeed, must necessarily be the case, since each was describing, in a scientific spirit, the principles involved in the production and propagation of sounds. It is, therefore, not surprising that a remarkable correspondence exists not only in the mode of treatment and language employed, but even in the graphic representations of the curves corresponding to various sounds.

Reis, however, did not content himself with the mere assertion of his ability to make his telephone transmit and reproduce intelligible articulate speech, but he actually accomplished it. Evidence of the most undoubted character exists, showing that both he and others talked through his instruments, and received communications through the same. Some of these witnesses are still alive, and rank among the most distinguished scientific men of Germany. Indeed, so well was the fact that speech had been transmitted by Reis known in Germany, that many firmly believed, on hearing of the commercial success of the Bell telephone in America, that the name referred to a particular form of Reis's telephone.

The Reis telephones as constructed by him will transmit intelligible articulate speech to-day, as can be testified by numerous able scientific men in America and Europe. The transmitter, as originally devised and constructed by Reis, is substantially the same as that employed in the commercial systems of telephony now in use.

Notwithstanding the following facts, the truth of which we believe has never successfully been controverted, viz.:

1st. That Reis expressly claimed that he was endeavoring to make an instrument that would transmit and reproduce articulate speech.

2d. That he did actually produce such an instrument and talked or listened through it, and permitted credible and trustworthy witnesses to so talk or listen through it; and

3d. That instruments constructed strictly in accordance with the instructions and descriptions of Reis will still talk, it is gravely asserted by some that the instrument invented by Reis was not a telephone at all, but a mere toy, intended, not for the transmission and reproduction of articulate speech, but merely for the transmission of musical tones. To deny that to be an articulating telephone that was claimed by its inventor to be constructed as such, that unquestionably operated as such, and that is still capable of operating as such, is, to say the least, open to grave suspicions either of want of fairness, or of an actual ignorance of the real facts of the case, that appear to be almost incredible.

It is not of course to be claimed for the original Reis instrument that it is as efficient in operation as the various instruments now in actual commercial use. But it is true that the instruments of to-day owe their superiority not so much to any new principle of construction or operation that has been introduced into them, but rather to their use of a metallic diaphragm in the place of the membranous one that was liable to variations in its tension by dampness, or to a better proportioning of parts, or of the means employed to readily adjust the same. Although this is freely admitted, yet the instrument left by Reis was far ahead of the apparatus figured and described by Bell in his application of February 14, 1876, since the former will talk, while the latter can scarcely be said to do so.

Of course we are not unmindful, in drawing these comparisons between the apparatus of Reis and Bell, that the latter, claims as the essential feature of his invention the use of what he styles the undu-

latory electrical current, without which, in his opinion, the transmission of articulate speech is an impossibility. He calls especial attention to the phraseology employed by Reis in describing his invention, when he speaks of the makes and breaks effected by the transmitting apparatus in the circuit, and claims that such apparatus could not transmit articulate speech. The argument concisely is as follows, viz.: The undulatory current is necessary for the transmission of articulate speech. Reis did not employ the undulatory current; therefore, Reis did not (could not) transmit articulate speech, (and this apparently without any serious effort to ascertain whether in point of fact Reis actually did transmit speech).

Granting the first premise here merely for the sake of argument, we reply as follows, viz., the Reis apparatus did and will transmit articulate speech, therefore Reis and not Bell is the true inventor of the undulatory current as applied to telephony.

This conclusion is so inevitable that it will readily be understood that the advocates of Bell are unwilling to admit the possibility of Reis ever having been able to speak through his apparatus, since such an admission is equivalent to an acknowledgment of the want of novelty of Bell's undulatory electrical current.

It is admitted, as must indeed be done, that the Reis apparatus will talk now, provided such skill in adjusting the same be brought to bear on it as has been acquired in the light of Bell's invention. To this we would answer that this is exactly the skill which we must admit was possessed by Reis, and which he acquired by reason of his extended experiments. Such a conclusion is inevitable, since nothing is absolutely necessary in the adjustment of the Reis apparatus that was not provided for in the same, nor is any addition to the same required. If, therefore, an expert of to-day can make the Reis apparatus talk, the presumption is manifest that Reis actually did what he and others claim that he did, namely, transmit speech through his apparatus by means of electrical currents whose intensity was varied by the action of the human voice on the transmitting apparatus.

There is no doubt that the written descriptions of Reis or of his contemporaries, concerning his apparatus, speak of the same as operating in consequence of what he terms makes and breaks in the circuit of the transmitting apparatus. In all forms of his apparatus he shows loose contacts that are caused by the vibrations of the membrane of the transmitting apparatus to vary the resistance of the circuit by

what Reis called the making and breaking of the same. This point in the description of the Reis apparatus is seized by the champions of Bell as a flaw, fatal to the claims of Reis as the true inventor of the articulating telephone. They apparently have accepted it as a "forlorn hope," and are perhaps to be congratulated for having made the most of it, having rung the changes on it and juggled with it until it seems to have acquired an importance in their eyes that it does not appear to us to possess. They claim that the operation of the Reis transmitter must necessarily be to produce abrupt makes and breaks in the continuity of the circuit connecting the transmitting and receiving instruments, and that, of course, such makes and breaks are inconsistent with the electrical transmission of articulate speech.

To the above argument, which in reality covers the only point in discussion between Reis and Bell, we submit:

1st. That even a casual reading of the descriptions of the Reis apparatus clearly shows that the inventor did not intend the same construction to be placed on the words describing the action of the voice on the contacts through the movements of the diaphragm, as the champions of Bell claim that he did. That is, that Reis did not construct his apparatus to obtain abrupt makes and breaks.

2d. That it can by no means be regarded as conclusively proved that the transmission of articulate speech necessitates the production by the transmitting apparatus of the undulatory electrical currents in the manner described by Bell.

That Reis did not contemplate the production of abrupt makes and breaks in the circuit may be clearly seen from his own description of his apparatus, which shows that he had fully grasped the necessity for his transmitting apparatus to impart such variations to the electric current as to reproduce in the receiving apparatus "vibrations whose curves shall be the same as those of any given tone or combinations of tones," since thus only, as he remarks, can we "receive the same impression as that tone or combination of tones would have produced on us."

Before, however, entering at length into a full discussion of the points above referred to, let us first see the actual character of the apparatus as Reis produced them.

The earliest transmitting apparatus made by Reis was that modeled after the human ear. In Fig. 1, which with Figs. 2, 4, 10 and 11, is

taken from S. P. Thompson's work on the Telephone, is shown various views of the transmitter, which was roughly carved in oak.

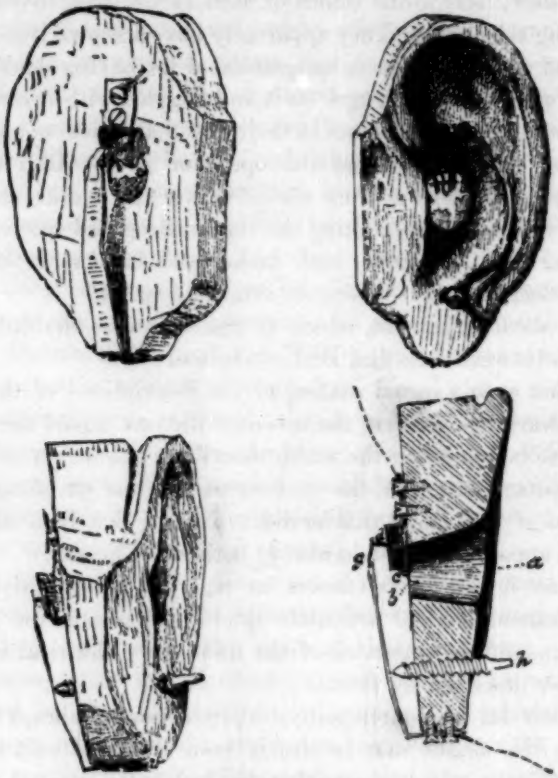


FIG. 1.—Reis Transmitter.—Human Ear Model.

An examination of this apparatus shows that it followed closely the arrangement of the human ear. For example, the cavity *a*, was closed at its further end by the membrane *b*, which took the place of the tympanic membrane. The chain of bones that connects the tympanum with the inner ear, was, in Reis's ear-model, represented by the bent lever *c d*, made of platinum wire. This lever, which was pivoted on a suitably supported horizontal axis, had its end *c*, securely fixed to the centre of the diaphragm *b*, by means of sealing wax, and was so arranged as to be able to follow all its motions. The pivot or axis, was placed near the centre of the lever and was supported in the manner shown in detail in Fig. 2.

The end *d*, of the bent lever rested with a loose contact against a spring *g*, near its upper end. This spring, whose length was about one inch, was furnished at its upper end with a slender spring strip of platinum foil. The adjusting screw *h*, was provided for the regulation of the degree of pressure between the end of the lever *d*, and its opposed surface of platinum foil at *g*.

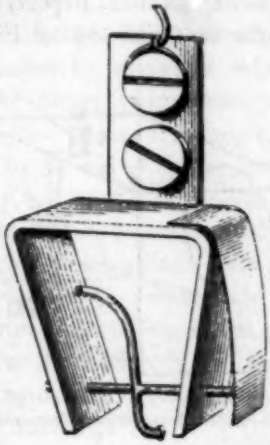


FIG. 2.—Details of Transmitting Lever.

The apparatus above described, was provided, as has been seen, with two loose contact points of metal, that were introduced as a variable resistance in the electrical circuit that connected the transmitting and receiving apparatus. When the voice of a speaker, talking into *a*, caused the membrane *b*, to be set into vibrations, the bent lever, carried the vibrations and transferred them from the membrane to the loose contacts between *g*, and *d*, thus introducing into the circuit variations in its resistance corresponding to the movements of the membrane or diaphragm *b*.

In Fig. 3 is shown another form of transmitting apparatus devised by Reis, and which is known as the bored-block transmitter.

Between the form shown in the human ear model and that shown in Fig. 3, there were several transitional forms, some of which are still persued in the physical cabinet of the Garnier Institute. These instruments were modifications of the human ear model. The details of the means they employed for varying the resistance at the loose contacts do not appear to have been preserved.

The bored-block model, shown in Fig. 3, was among the most important of articulating telephone transmitters constructed by Reis. We prefer therefore to give verbatim Reis's description of the same, together with a few prefatory remarks. We quote from a translation from Prof. S. P. Thompson's work, of an article entitled "On Telephony by the Galvanic Current, by Philipp Reis." This article appeared in the "Jahresbericht" (Annual Report) of the Physical Society of Frankfort-am-Main, for 1860 and 1861. Fig. 3 is taken from this article.

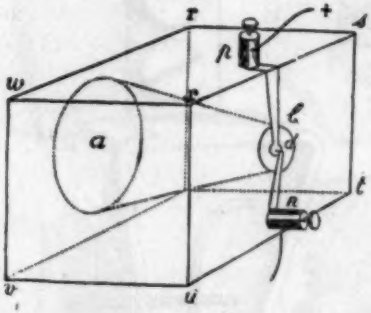


FIG. 3.—Reis's Bored-Block Transmitter.

After alluding to his early fondness for experimental physics, and to his belief, nine years previous to the date of the above article of the possibility of transmitting tones by the galvanic current, he spoke of having but really begun the problem, when discarding the idea of producing the tones by mechanism similar to the vocal organs, he made the great step of endeavoring to produce them by means of apparatus resembling the auditory organs. He then discusses the nature of sounds or tones, and the action of the ear in carrying the same to the auditory nerve. He points out very clearly that what the auditory nerve perceives is the action of a force, which force may be represented graphically according to its direction and magnitude by a curve. He discusses the forms such curves would have when produced by simple tones, and by complex tones, and then speaks as follows, viz.:

"It follows from the preceding that:

(1.) Every tone and every combination of tones evolves in our ear, if it enters it, vibrations of the drum-skin, the motions of which may be represented by a curve.

(2.) The motions of these vibrations evoke in us the perception

(sensation) of the tone; and every change in the motion must change the sensation.

As soon, therefore, as it shall be possible at any place and in any prescribed manner, to set up vibrations whose curves are like those of any given tone or combination of tones, we shall receive the same impression as that tone or combination of tones would have produced upon us.

Taking my stand on the preceding principles, I have succeeded in constructing an apparatus by means of which I am in a position to reproduce the tones of divers instruments, yes, and even to a certain degree the human voice. It is very simple, and can be clearly explained in the sequel, by the aid of the figure. (See Fig. 3.)

In a cube of wood, *r*, *s*, *t*, *u*, *v*, *w*, *x*, there is a conical hole, *a*, closed at one side by the membrane, *b* (made of the lesser intestine of the pig), upon the middle of which a little strip of platinum is cemented as a conductor of the current [or electrode]. This is united with the binding screw, *p*. From the binding screw, *n*, there passes likewise a thin strip of metal over the middle of the membrane, and terminates here in a little platinum wire which stands at right angles to the length and breadth of the strip."

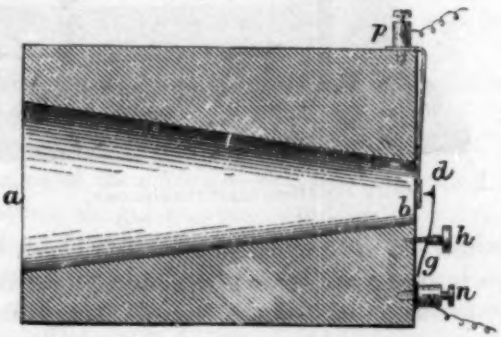


FIG. 4.—The Bored-Block Transmitter (later form).

In the form of transmitter shown in Fig. 3, no means are provided for the regulation of the pressure between the contact points, *b*, and *d*. In a transmitter of this form used by Reis, and afterwards given to Prof. Böttger, and now in the possession of Dr. Stein, of Frankfort, to whom it was given by Prof. Böttger, the details of construction are identical, with, however, this difference, that such regulating device is there provided. This later form is shown in Fig. 4. The regulating

screw referred to is shown at *h*. Since such a device was placed by Reis in his human ear transmitter, it is not unreasonable to suppose that it was placed in the bored-block transmitter by Reis himself.

The presence of these screws for regulating the degree of contact between the loose contacts that are moved by the diaphragm is not without its significance in the true explanation of the manner in which Reis designed his apparatus to operate, as we shall hereafter explain.

The next form of transmitter is shown in Fig. 5. There appears to have been several unimportant modifications between this transmitter and that shown in Fig. 3.

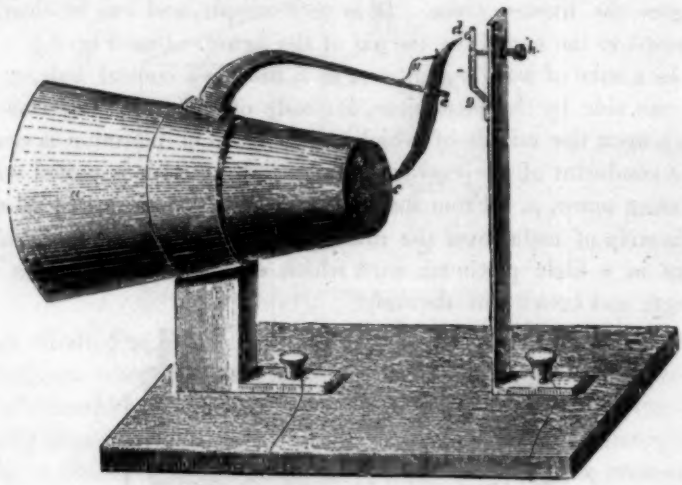


FIG. 5.—The Reis-Legat Transmitter.

This transmitter has been so named after Von Legat, Royal Prussian Telegraph Inspector at Cassel, who prepared a description of the same for the "Journal of the German-Austrian Telegraph Association in 1862." Some questions have been raised whether this form of apparatus was really invented by Reis, since no original apparatus answering this description has been found. The apparatus, however, does not differ substantially from that employed by Reis during his lecture before the Freies Deutsches Hochstift, at Frankfort, so that we may safely ascribe the apparatus to Reis.

The description by Legat of the transmitter is quite minute. We prefer to give it as taken from a translation of the article before alluded to.

"The tone transmitter, Fig. 4, *A*" (see Fig. 5 in the article) "consists of a conical tube, *a*, *b*, about 15 centimeters in length, having a front opening of about 10 centimetres, and a rear opening of about 4 centimeters.

"It appears by practical experiments that neither the material of the tube, nor any increase in its length, influenced the accuracy of the action of the apparatus. An enlargement of the diameter of the tube impairs the working of the apparatus, and it is desirable that the inner surface of the tube be as smooth as possible. The smaller or rear end of the tube is closed by a collodian membrane, *o*, and upon the centre of the circular surface of this membrane rests one end, *c*, of the lever, *c*, *d*, the supporting point, *e*, of which is sustained by a bracket, and is kept in electrical connection with the metallic conductor. The proper lengths of the respective arms, *c*, *e*, and *e*, *d*, of this lever are regulated by the laws of the lever. It is advisable to make the arm, *c*, *e*, longer than the arm, *e*, *d*, in order that the least motion at *c*, may operate with greatest effect at *d*. It is also desirable that the lever itself may be made as light as possible, that it may follow the movements of the membrane. Any inaccuracy in the operation of the lever, *c*, *d*, in this respect will produce false tones at the receiving station. When in a state of rest the contact at *d*, *g*, is closed, and a delicate spring, *u*, maintains the lever in this position." . . . . .

"Upon the standard, *f*, is arranged a spring, *g*, with a central point corresponding to the central point, *d*, of the lever, *c*, *d*; the position of *g*, is regulated by the screw, *h*." . . . . . .

The operation of the apparatus described is as follows:

"When at rest the galvanic circuit is closed. When the air, which is in the tube *a*, *b*, of the apparatus, Fig. 4, *A*, (our Fig. 5,) is alternately condensed and rarified by speaking into it (or by singing or introducing the tones of an instrument), a movement of a membrane closing the smaller end of the tube is produced, corresponding to such condensation or rarefaction. The lever *c*, *d*, follows the movements of the membrane, and opens and closes (*offnet und schliesst*) the galvanic circuit (*kette*) at *d*, *g*, so that at each condensation of the air in the tube the circuit is opened, and at each rarefaction the circuit is closed (*ein oeffnen und ein Schliessen erfolgt*)."

The receiving apparatus used in connection with this form of transmitter was quite different in its construction from that employed in connection with the transmitters already described.

Prof. S. P. Thompson, in his work on the Telephone, figures the apparatus shown in Fig. 6, on the authority of Mr. Horheimer, a mechanician who aided Reis in the construction of the apparatus. The platinum contacts *c*, and *b*, placed as shown, had their contact pressure regulated by means of the adjusting screw *h*, the contact *c*, was connected to the strip *g*, of spring brass. The wooden case *a*, *b*, differed in no respect from that formerly employed.

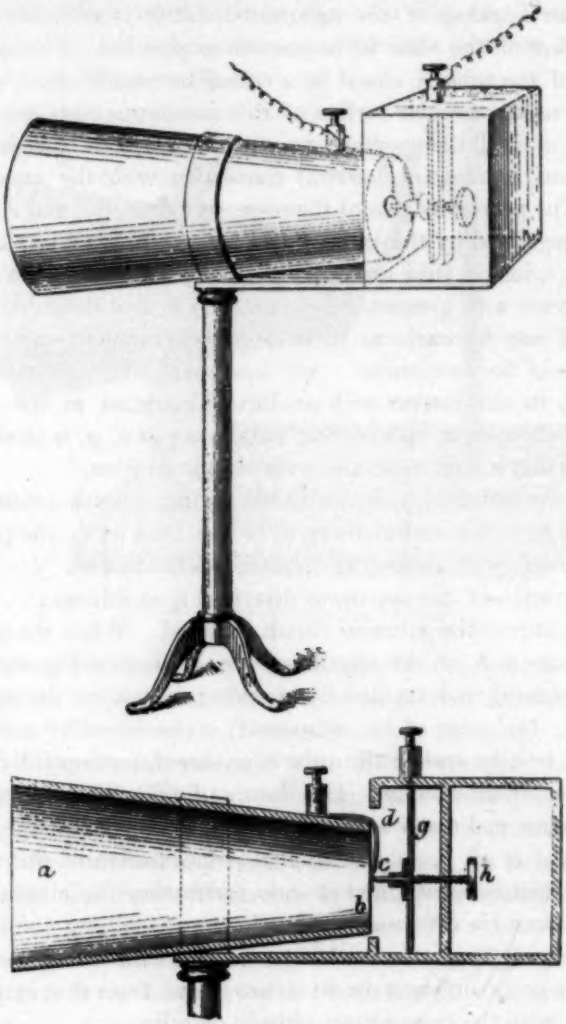


FIG. 6.—The Reis (Horheimer) Transmitter.

This apparatus appears to have been very compact, and doubtless was capable of yielding excellent results.

The form in which Reis left the transmitting apparatus at the time of his death is shown in Fig. 7, connected with a receiving apparatus. This is the form in which it was best known in cabinets of philosophical apparatus outside of Germany. The author is indebted to Müller-Pouillet's "Lehrbuch der Physik und Meteorologie" for the cuts.

The mouth-piece *S*, Fig. 7, was provided with a flaring end and passed into one side of a hollow square or rectangular box *A*. A membrane of bladder is stretched over a circular aperture in the hinged lid of the box. A small platinum strip secured to the centre of the diaphragm is connected with the binding post *a*, by means of the platinum strip *f*. The piece, *h g i*, of metal, has one end resting on the metal pillar *l*, while its other end *i*, is provided on its under side with a platinum point that dips into mercury contained in the hollow pillar *k*. At the angle *g*, of this metallic strip, is a small platinum pin *p*, that rests in contact against the platinum piece secured to the centre of the diaphragm. The mercury in *k*, is in electrical connection with the binding post *l*.

This form of transmitter, therefore, like the others, was dependent on the variations produced by the sound waves in the degree of contact of the platinum points placed in the circuit of a battery.

The transmitting apparatus as left by Reis was provided with an electro-magnetic call. In the model of the Reis telephonic apparatus, for philosophical cabinets, as constructed by Koenig, of Paris, this magnetic call is made in the shape of an electro-magnet with an ordinary hand key for making and breaking the circuit of the same. In Plate I, are shown photographic views of such transmitting apparatus, furnished by Koenig in 1874, for the Smithsonian Institute, Washington.

This apparatus was designed for the purposes of a call. It is thus described by Reis in a prospectus he prepared to accompany his apparatus: "As regards the telegraph apparatus placed at the side, it is clearly unnecessary for the reproduction of tones, but it forms a very agreeable addition for convenient experimenting. By means of the same, it is possible to make oneself understood right well and certainly by the other party. This takes place somewhat in the following manner: After the apparatus has been completely arranged, one

convinces oneself of the completeness of the connection and the strength of the battery by opening and closing the circuit, whereby at *A*, the stroke of the armature is heard, and at *C*, a very distinct ticking.

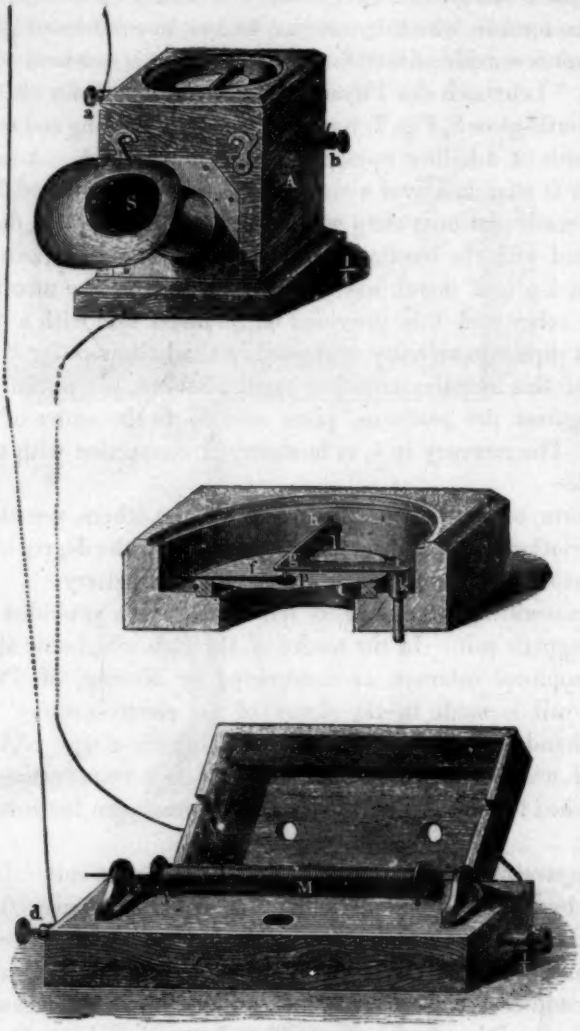
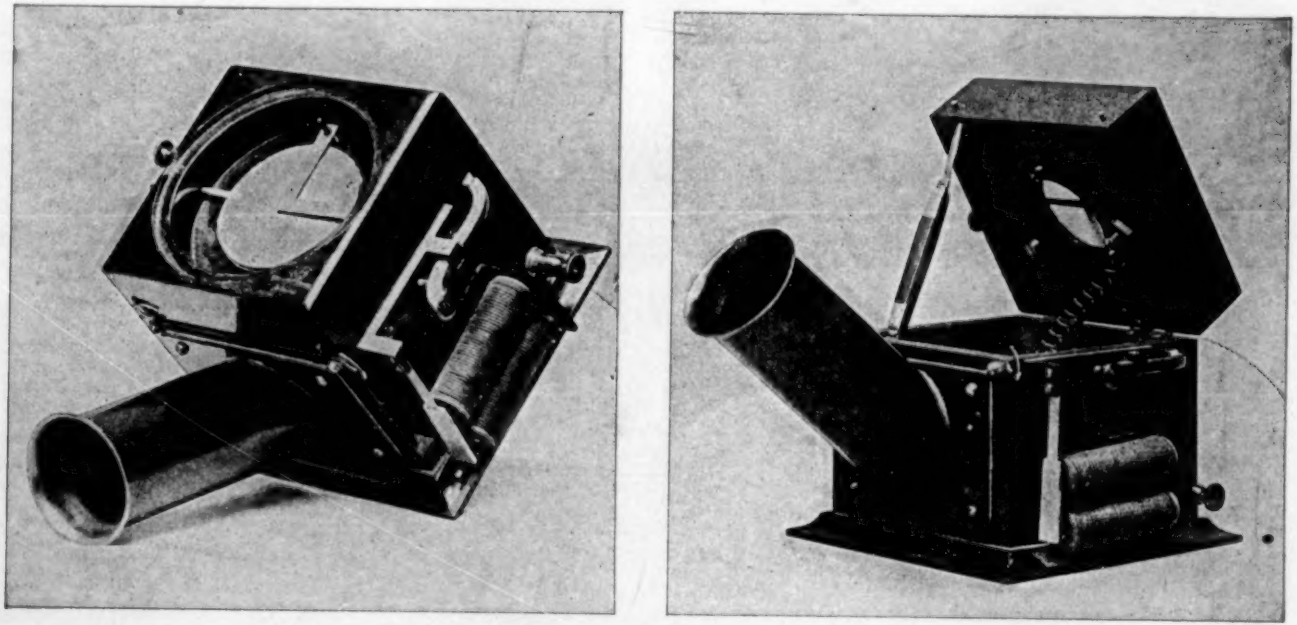
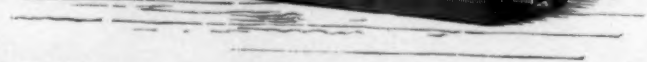


FIG. 7.—Reis's Cabinet form of Transmitter.

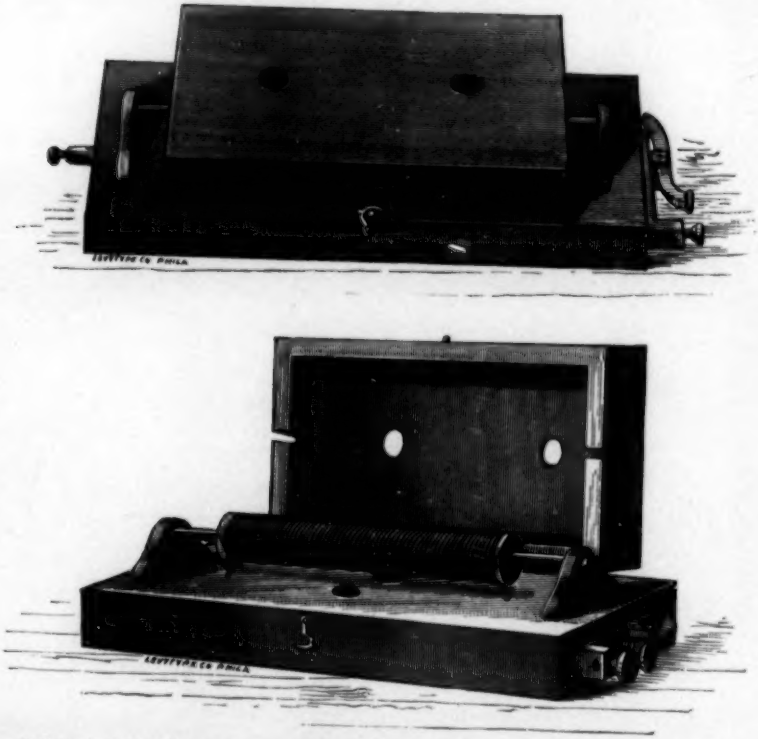
"By rapid alternate opening and closing at *A*, it is asked at *C*,



THE REIS (KOENIG) TRANSMITTER. SMITHSONIAN MODEL.



THE REIS (KOENIG) RECEIVER. SMITHSONIAN MODEL.



THE REIS (KOENIG) RECEIVER. SMITHSONIAN MODEL.

whether one is ready for experimenting, whereupon *C*, answers in the same manner.

"Simple signals can by agreement be given from both stations by opening and closing the circuit one, two, three, or four times; for example: 1 beat = sing, 2 beats = speak, etc."

Reis employed various forms of receivers. His earlier forms, as well as the one he appears to have finally adopted when he placed his instruments before the world, is that shown in connection with Fig. 7. This form consisted essentially of a coil, *M*, of insulated wire wrapped around a core of soft iron or steel. The ends of this coil were placed in the line circuit joined, as shown in the figure, at one end to *b*, and connected at the other end to *a*, through the poles of a suitable voltaic battery.

When, therefore, the speaker spoke into the mouthpiece at *S*, the diaphragm was set into vibration and produced variations in the contact between the platinum point that caused corresponding variations in the current flowing through the coil *M*, at the receiving station. These variations in the current produced movements in the iron core of *M*, that reproduce the sounds causing them. The hollow, resonant case surrounding the core of *M*, serves as a sounding-board to strengthen the tones of the receiver.

We again quote from the translation of the article in the *Jahresberichte* for 1860–1861, already referred to. It will be remembered that Reis is speaking of his "bored-block transmitter," shown in our Fig. 3. Its action was, however, quite similar with that of the transmitting apparatus shown in Plate I. This transmitter was connected with a receiver similar to that shown at the bottom of Fig. 7.

"If new tones or combinations of tones, are produced in the neighborhood of the cube, so that waves of sufficient strength enter the opening *a*, they will set the membrane *b*, in vibration. At the first condensation the hammer-shaped little wire *d*, will be pushed back. At the succeeding rarefaction it cannot follow the return-vibration of the membrane, and the current going through the little strip (of platinum) remains interrupted so long as the membrane, driven by a new condensation, presses the little strip (coming from *p*), against *d*, once more. In this way each sound-wave effects an opening and a closing of the current.

"But at every closing of the circuit the atoms of the iron needle lying in the distant spiral are pushed asunder from one another

("Müller-Pouillet, Lehrbuch der Physik," p. 304, vol. ii, 5th ed.). At the interruption of the current the atoms again attempt to regain their position of equilibrium. If this happens then in consequence of the action and reaction of elasticity and traction, they make a certain number of vibrations, and yield the longitudinal tone of the needle. It happens thus when the interruptions and restorations of the current are effected relatively slowly. But if these actions follow one another more rapidly than the oscillations due to the elasticity of the iron core, then the atoms cannot travel their entire paths. The paths traveled over become shorter the more rapidly the interruptions occur, and in proportion to their frequency. The iron needle emits no longer its longitudinal tone, but a tone whose pitch corresponds to the number of interruptions (in a given time). But this is saying nothing less than that the needle reproduces the tone which was imparted to the interrupting apparatus.

"Moreover, the strength of this tone is proportional to the original tone, for the stronger this is, the greater will be the movement of the drum-skin, the greater therefore the movement of the little hammer the greater, finally, the length of time during which the circuit remains open, and consequently the greater, up to a certain limit, the movement of the atoms in the reproducing wire (the knitting needle), which we perceive as a stronger vibration, just as we should have perceived the original wave.

"Since the length of the conducting wire may be extended for this purpose, just as far as in direct telegraphy, I give to my instrument the name "Telephone."

In Plate II is shown the form given by Reis, in the receiving apparatus as constructed by Koenig, of Paris. It will be seen to be essentially the same as in the form taken from "Mueller-Puillet."

The cuts shown in Plate II are reproductions from photographic views taken of the telephonic apparatus furnished the Smithsonian Institute by Koenig in 1874. They are companion instruments to those shown in Plate I. The resonant case is made of thin elastic wood. The magnetic call and telegraphic key are seen on the side of the apparatus.

It is very evident, in even casually examining this form of apparatus, that the resonant call is very badly disposed to receive the slight movements of the iron or steel core of the instrument. Instead of placing the rod with its end firmly against the sounding-box, it rests on its side, near its ends, on the wooden supports, in the position shown. This probably accounts for the hinged top of the case having

slots cut in its lower edge, and being firmly held against the iron core by means of the latch.

A preferable form of receiver shown in Fig. 8, is known as the violin receiver.

FIG. 8.—Reis's Violin Receiver.

The violin receiver was one of the earliest forms of receiver employed by Reis in his experiments. The original of this form of apparatus is now in the possession of the Garnier Institute, in Germany.

In the description of the Reis apparatus by Inspector Legat, a form of receiver was employed quite distinct from those already described.

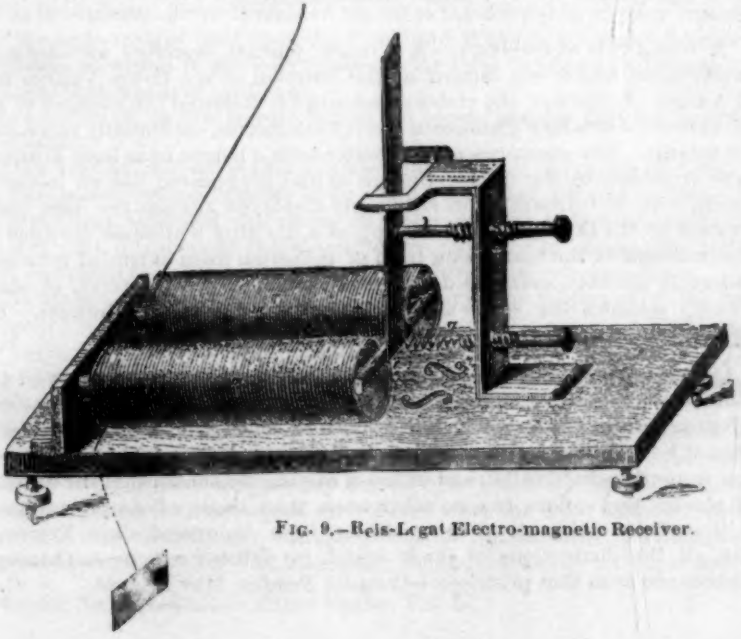


FIG. 9.—Reis-Legat Electro-magnetic Receiver.

In this form of receiver the electro-magnet, *mm*, has its coils placed in the circuit of the transmitting apparatus shown in connection with Fig. 5, one terminal passing to earth. This magnet is placed as shown and firmly attached to the sounding board, *n*. An armature, attached to a long, but light and broad lever, *i*, faces the poles of the electro-magnet, *mm*. The lever, *i*, which bears the armature at its lower end, is suspended after the manner of a pendulum, from the upright standard, *k*. The regulating screw, *l*, and spring, *q*, are furnished for the regulation of its motion.

When now the sound waves impinging against the membrane of the transmitting apparatus produce variations in the intensity of the electrical current traversing the circuit, the magnetization and demagnetization of *m*, *m*, produce corresponding vibrations in its armature, which vibrations are communicated to the air surrounding the apparatus, both directly by the armature itself, and indirectly by the beam, *i*, connected therewith.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, June 10, 1885.

(To be continued.)

A GREAT WATER-SPOUT.—A French journal describes an enormous water-spout which was formed at the junction of the rivers Vannes and d'Auray. In spite of the violent west wind it followed the channel of the river northwards for a distance of about 4 kilometres, continually increasing in volume. The enormous mass of water with a height of at least 30 metres was traversed by the rays of the sun so that it appeared like an immense prism with its brilliant colors admirably displayed against the dark background of the sky. A superb canopy of a dazzling whiteness crowned its summit and at the base a long train of yellowish foam extended for a considerable distance over the dark green water. After an interval of about twenty minutes the spout suddenly burst with a clap of thunder.—*Les Mondes*, Sept. 18, 1884. C.

CONTRASTS OF COLOR.—Chevreul after referring to his discovery of the simultaneous contrast of colors in 1828, reports the following conclusions: Thomas Young's theory of three primitive colors, red, green and violet, cannot be admitted unless good reason can be shown for excluding the yellow from the primitive list, and unless it can also be shown that the contrast of shades and colors has no other basis than those of simple mixture. Although the principle of contrasts has been discovered since Newton's day, all the distinctions of shade which he pointed out are in thorough accordance with that principle.—*Comptes Rendus*, May 26, 1884. C.

Book Notices.

MEDICAL DIRECTORY OF PHILADELPHIA, PENNSYLVANIA, DELAWARE, AND THE SOUTHERN HALF OF NEW JERSEY. Edition for 1885. Pp. 400. P. Blakiston, Son & Co.

This directory is a great improvement over any directory of its kind that has been issued. In its four hundred pages are found everything pertaining to the medical interests of the State and city. It contains lists of the Physicians in Philadelphia, Pennsylvania, and adjoining States, the dentists and druggists of the city, as well as the details required for a good understanding of the organizations, institutions, and State and city matters connected with medicine. The laws of Pennsylvania bearing upon all matters incorporated in the book are a new feature and of great value. The index, material, and type are well arranged to facilitate reference. F.

THE DESIGNING OF ORDINARY IRON HIGHWAY BRIDGES. By J. A. L, Waddell, C.E., etc. New York: John Wiley & Sons, 15 Astor Place. 1885.

This book is one of the few amongst the great number of scientific books annually published which will receive and which deserves full commendation.

It is invaluable to engineers and students, and to some degree also to municipal and county commissioners, upon whom devolves the duty of selecting new bridges.

The information given therein in regard to the designing of pony trusses and through-bridges built upon the Pratt and Whipple systems—the class of bridges of which it specially treats—is the most thorough and the most practical that was ever published.

As a text-book, in this respect, it does not appear possible that it ever will be excelled.

It is a kind of labor-saving book, presenting the essential points in designing the class of bridges spoken of in a clear, tabulated manner, adding, at the same time, sufficient discussion upon the question of stresses to which the different members of the structure are subjected to prevent the book from assuming the character of a dry and monotonous reference-book.

The author, evidently, is a thorough master of the subject of which he writes.

CURVE TRACING IN CARTESIAN CO-ORDINATES. By William Woolsey Johnson. New York: John Wiley & Sons, 1884.

Professor Johnson has given in this small volume an exposition of a method of tracing plane curves, represented algebraically by equations between two variables and of any degree. He considers especially those rather complicated curves which are studied after the conic sections. His method is very elementary; without the use of the calculus. As a mathematical exercise nothing could be better for the student in technical insti-

tutions than interpreting, on a sheet of drawing paper, the curves in question by any method of interpretation.

That a subject which is grasped most fully with the use of the calculus, may be treated in a really satisfactory manner without such aid, we doubt. We cannot understand the persistence, still lingering, which characterizes the efforts made to dispense with the calculus in practice; an instrument that has proved so grandly useful all through applied mathematics. As a matter of fact, some abstruce problems are capable of solution with the most elementary knowledge of mathematics; but what cumbersome, involved reasoning! Practitioners are said to forget their knowledge of the calculus; but they should not: it is a tool which they need to keep ready for use. When the mathematics have been *thoroughly* learned once, they may lay dormant in the mind for quite a period of time, ready to spring into activity on refreshing the memory by a slight review. C. A. E.

A Simple Rule to Determine the Length of a Pendulum. By G. Morgan Eldridge.

Set down the number of beats that the pendulum makes to a minute as the denominator of a fraction, and 60 as the numerator. Reduce the fraction to its lowest terms. Square the numerator and denominator by multiplying each by itself.

Multiply the length of a seconds beating pendulum, 39·2 inches, by the squared numerator and divide the product by the squared denominator.

The length of a pendulum is not the length to the end of the ball, but from the point of suspension to the centre of oscillation, which is at some distance above the centre of the ball—this distance depending upon the weight of the pendulum rod in proportion to that of the ball.

To illustrate: a pendulum beating 90, the fraction is $\frac{60}{90}$, its lowest terms are $\frac{2}{3}$, which squared is $\frac{4}{9}$; multiplying 39·2 by 4 and dividing by 9 gives 17·42 inches. A pendulum beating 120, the fraction is $\frac{60}{120}$, its lowest terms $\frac{1}{2}$, which squared is $\frac{1}{4}$; multiplying 39·2 by 1, dividing by 4, gives 9·8 inches. A pendulum beating 30, the fraction is $\frac{60}{30}$, its lowest term s $\frac{2}{1}$, which squared is $\frac{4}{1}$; multiplying 39·2 by 4, dividing by 1, gives 156·8 inches.

[This is not intended for the scientist, but for the practical workman who has forgotten the square root—if he ever learned it—who has no idea of the nature of a logarithm, and to whom a formula is Greek. It will be entirely within the range of his comprehension and application, and the results are correct.—E.]

The Principles of Ventilation and Heating, and the Practical Application. By John S. Billings, M.D., LL.D. (Edinb.), Surgeon in U. S. Army.

The work under consideration is peculiarly characteristic of a class which has appeared of late years in all departments of study, being designed to bridge the chasm that hitherto divided the branches of knowledge commonly distinguished as scientific and practical—distinctions which works like the present tend to obliterate.

The author states that he was actuated in the production of his work by the endeavor to comply with a request for "some plain, practical directions

as to the best methods of arranging the ventilation of a building, to be given, as far as possible, in the form of specifications which can be easily understood by an intelligent builder, and not in the form of abstract mathematical formulas," and, while disclaiming the ability to comply strictly with such a request, and to establish a royal road to knowledge, he has attempted to render the progress less difficult.

That he has succeeded in this laudable effort, a perusal of the work demonstrates: and with a full appreciation of the importance of the subject with which it deals we commend it to the public at large as well as to those specially interested. W. B. C.

SPON'S MECHANICS' OWN BOOK: a Manual for Handicraftsmen and Amateurs. London and New York: E. & F. N. Spon, 1885.

This is a compendium of information useful alike to the professional and to the amateur mechanic. The latter will find in it the knowledge which he requires for his particular hobby, whatever that may be, and the former must be rarely skilled in his art if he cannot find in its pages points in his own specialty which have hitherto escaped his research; and when he needs—as every one does sometimes need—to explore kindred branches of art, he will find in this book a guide, a companion and a serviceable friend. G. M. E.

PHYSICIAN'S VISITING LIST FOR 1885. 12mo. Philadelphia: P. Blakiston, Son & Co., Publishers.

This standard book, now in the thirty-fourth year of its publication, and so well known to physicians, calls for a few words of praise, it being the aim of its publishers constantly to add to its excellence without much increasing the size of the book. In addition to the blank leaves, properly ruled for a visiting list, monthly memoranda, etc., we have Marshall Hall's method for treating asphyxia; Sylvester's for producing artificial respiration; a list of new remedies by Dr. Henry Morris, in which cocaine is singularly omitted; the usual dose table; poisons and their antidotes, and the decimal system of weights and measures which we are glad to see is making such headway in scientific medicine, leaving little or nothing to be desired in this indispensable volume for the pocket of the busy practitioner. I. N.

BACTERIAL PATHOLOGY; a series of papers on the Exhibits at the Biological Laboratory of the Health Exhibition under the charge of Watson Cheyne. 12mo. New York: Industrial Publication Company. 1885.

The scientific as well as popular interest in this subject is so great that it has been thought well to collect the series of papers which have appeared in the London *Lancet*, in this little volume which is literally running over with material for thought and action, by our constituted authorities. The micrococus of pneumonia and the bacillus of typhoid fever and tubercle are briefly described, and illustrated with some excellent wood-cuts. We have also the bacilli existing in milk and butter given, while the pamphlet concludes with the various methods used in the laboratory for cultivation

of the germs and the media employed. The researches of Pasteur, Koch, Formad and others have made this comparatively new subject so important to man, that any attempt to give light and increase knowledge is very important, and the above series of papers form a good introduction to more elaborate works on the subject. I. N.

ANNUAL REPORT

OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE, FOR THE SESSIONS 1884–1885.

The Drawing School year, which ends this evening, has been productive of good results, and will compare favorably with past years, except that the number of students has not been up to the average, the general stagnation of business having had its effect on this as on everything else. The system and methods of teaching have been improved, models illustrating the principles of projection have been furnished, a number of standard typical machine models have been supplied, and the collections of prints of geometrical problems, orthographic projections and machine construction, has been largely increased.

The school affords an excellent opportunity for a diligent, attentive and interested student to obtain a knowledge of the principles and practice of drawing, and numerous instances of material advantage arising from it have occurred. The ultimate benefit to any individual depends upon his own capabilities and exertions, the school affording every facility for him to make the most of them. Artisans, mechanics and those connected with manufacturing, have, as a rule, made the best progress; but there have been very few indeed who have not been benefitted. The importance of a knowledge of this branch of technical education is gradually becoming more appreciated and every effort should be made to encourage a study so conducive to the material development of the country, and so in harmony with the genius of the people. The system of this school combines theory and practice, so arranged as to accomplish the most useful results in the least time. * * * * * The custom of granting certificates to those students who have attended four terms is continued, but all those who are really interested in their studies are strongly advised to continue, as very few succeed in obtaining all the possible benefit in that time.

The drawings exhibited this evening present a fair average of the work of the year.

The Free Hand Class shows drawings from the flat and also from casts. The Architectural Class shows designs, plans and details for dwellings, most of which are original and some for use. These classes have been under the instruction of MR. EDWARD S. PAXSON and MR. CLEMENT REMINGTON.

The Junior Mechanical Classes show a course of problems in Plane Geometry, which gives the student, in addition to a knowledge of the problems themselves, a familiarity with the various lines, shapes and magnitudes, an appreciation of the importance of care and accuracy, and a knowl-

edge of the use of instruments. These classes also commence the study of projections, a clear understanding of which is so essential and, at the same time, so difficult to obtain. The use of a series of models, with the object surrounded by transparent planes, has materially aided in elucidating this subject. These classes have been in charge of MR. GEORGE S. WILLITTS and MR. WILLIS H. GROAT.

The Intermediate Classes under MR. CARL BARTH, have gone very thoroughly into Projections, Intersections and Developments, which constitute the basis of exact drawing for mechanical purposes and are of great importance, although usually neglected. In this school much time and attention is given to this branch.

The Senior Mechanical Class under the instruction of the Director Mr. WILLIAM H. THORNE, pursues a course of practical draughting, making working drawings from copies, sketches and models, applying the principles already learned, and giving particular attention to the technicalities and methods best adapted to actual work.

The following students deserve Honorable mention for their attention, industry and progress:

In the Senior Mechanical Class.

James G. Davis, Eb. W. Thomas, J. E. Pugh,
Max Uhlmann, Charles von Berger, Joseph Herbick.

In the Intermediate Mechanical Classes.

F. W. Langell, J. C. Biddle, Clarence E. Wood,
William H. Schalliol, J. McEachren, James F. Deimling,
E. Morgan Denney, George S. Iredell, W. J. Dignan.

In the Junior Mechanical Class.

T. Edward Schiedt, Samuel Wilson Goodwin, E. T. Taylor,
Charles R. Middleton, Franklin L. Kellner.

In the Architectural Class.

Rodger M. Coombs, Thomas W. Draper, John Dueringer,
Bernard Rimer, Wilbert H. Smith, George Highley,
Minnie M. Parker.

In the Free Hand Class.

William Himelspark, Frank Pierce Homer, James J. Dunn,
Mary H. Goudkop, William Rothfuss.

The following students are awarded scholarships from the B. H. Bartol fund, entitling them to free attendance during the next term, beginning September 29, 1885:

J. E. Pugh, T. Edward Schiedt, Rodger M. Coombs,
F. W. Langell, J. C. Biddle, William Himelspark.

They will present themselves to the Actuary at that time and receive their tickets.

The following students having attended the school during four terms, are awarded certificates to that effect:

James G. Davis,	Edgar L. Hallowell,	Eb. W. Thomas,
J. E. Pugh,	William S. Lawrence,	A. Bonfidis,
Max Uhlmann,	Gerhard Walton,	Charles von Berger,
Warren Dexter,	Joseph Herbick,	James J. Dunn,
Viggo Torbensen,	Bernard Rimer,	Charles Regester,
George Highley,	J. H. McCullough,	E. G. Kolb,
George McArthur,	John McCoy,	George D. Holt,
	George Löwe.	

The recipients of these certificates ought not to consider that they have completed their education in drawing, but should continue at the school until convinced that they have received all the benefit that is to be derived from it.

WILLIAM H. THORNE,
Director.

Philadelphia, May 21. 1885.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, June* 17, 1885.]

HALL OF THE INSTITUTE, June 17, 1885.

WM. P. TATHAM, President, in the chair.

Present—108 members and 9 visitors.

The election of thirteen new members was reported.

Recommendations for the award of the "JOHN SCOTT Legacy Premium and Medal" were reported from the Committee on Science and the Arts, to MORRIS L. ORUM, for his improvement in Locks; ORLANDO W. SPRATT, for his Mercury-Seal Trap; and ISAAC TOWNSEND, for his improved Tent-slip.

The recommendations were severally approved, and the Secretary was directed to communicate the action of the Institute to the Committee on Minor Trusts of the Board of City Trusts.

MR. W. CURTIS TAYLOR read the paper of the evening, "On Composite Photography." The paper, with lengthy discussion thereon, has been referred to the Committee on Publication.

The Secretary's report embraced an account of the recent experiments of Mr. Della Torre, of Baltimore, to determine, by the ingenious device of obtaining an echo therefrom, the proximity of an iceberg or other obstruction in the path of a vessel. The apparatus employed consisted of a musket, to the muzzle of which a speaking-trumpet was attached, and from which

blank cartridges were fired in the direction of passing vessels. The results are reported to have been encouraging.

The Secretary gave a description also of some interesting applications of isochromatic photography for which he was indebted to, Mr. Ives.

To prevent the counterfeiting of bank notes by photo-lithography or photo-engraving, they have been printed in two or more colors, which present a strong contrast to the eye, but come out equally dark in an ordinary photograph, making it impossible to reproduce either design by itself. The Secretary exhibited two examples of this two-color printing, by the American Bank Note Co., which had been submitted to Mr. Ives, to see if they were proof against counterfeiting by means of his isochromatic process. One was printed in dark red and light lemon-yellow, the other in dark blue and light lemon-yellow. Mr. Ives succeeded in obtaining good photographs of the designs printed in red and blue, without showing the yellow at all. In ordinary photographs, made for comparison, the light yellow comes out as dark as the red, and darker than the blue.

The Secretary likewise referred to the recently published results of investigations by Prof. Edward S. Wood, of the Massachusetts State Board of Health, which exhibit an alarming and indiscriminate use of arsenic in various branches of manufacture.

He read a copy of a letter of DR. BENJAMIN FRANKLIN, which had lately been brought to light, in which were some highly interesting suggestions respecting the introduction of canals into the Province of Pennsylvania. The letter is addressed to S. RHOADS, Esq. (who was Mayor of Philadelphia in the historic year, 1776), and is dated London, August 22, 1772. It was discovered among the family relics of a descendant of Mr. Rhoads, and who is a member of the Institute.

The Albo-Carbon Light, F. Hickman's Hose-Coupling, and H. Weindel's Steady-Blast Air Pump were exhibited and described.

MR. OTTO LŬTHY exhibited and remarked upon some specimens of molasses and sugar grown upon the recently reclaimed swamp lands in Florida, known as the "Everglades," which a party of Philadelphia capitalists have for some years been engaged in draining. Several millions of acres have already been drained, and soil and climate are reported to be admirably adapted for growing the sugar cane.

The following, on Prof. Houston's motion, numerously seconded, was adopted:

Resolved, That the Franklin Institute respectfully requests the Board of Health, of the City of Philadelphia, to take such measures as may be necessary to prevent the pollution of the Schuylkill river by the National Encampment about to be held at Fairmount Park.

Adjourned.

WILLIAM H. WAHL, *Secretary.*